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ADVISORY GROUP FOR AEROSPACE RESEARCH & DEVELOPMENT

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Recruiting, Selection, Training and Military Operations of Female Aircrew

(Le Recrutement, la Sélection, l'Entraînement et les Opérations Militaires du Personnel Navigant Féminin)

NORTH ATLANTIC TREATY ORGANIZATION

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(ORGANISATION DU TRAITE DE L'ATLANTIQUE NORD)

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Papers presented at the Aerospace Medical Panel Symposium held in Tours, France, 4th to 5th April 1990.

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- Continuously stimulating advances in the aerospace sciences relevant to strengthening the common defence posture;
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A BRIEF INTRODUCTION TO THE HISTORY OF WOMEN IN AVIATION

by

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In The Very Early Days

Women have been involved in aviation since 1784 when Madame Elizabeth Thible went aloft in a Montgolfier balloon over Lyon, France. Generally speaking when women first took to the air in the pioneer days of flight, their efforts frequently met with scorn and ridicule. Flying was a male preserve, and many were determined to keep it so. But from the late 1920's onward, a spirited group of women flyers demanded to be treated as full fledged professionals rather than as publicity-seeking amateurs. Their exploits, particularly in the field of long distance flying, captured the imagination and the headlines of the world. They flew over trackless deserts and ocean wastes in single-engined planes which had a top speed of 80 or 100 mph, armed with only the crudest maps and often simply leaning over the side to see where they were going.

The first powered sustained flight in history was made by the Wright brothers at the end of 1903. By 1911, women, too, were in the air. The honour of being the first woman in the world to earn a pilot's licence belongs to Mme Elise de Laroche, who qualified for the thirty-sixth brevet issued by the French Aero Club (1910). The first British woman to qualify for her pilot's licence was Mrs Hilda Hewlett.

Women pioneers in aviation were making remarkable solo flights. Lady Bailey and Lady Heath were both flying routes between England and Africa in 1928 and 1929. In 1930 Amy Johnson flew alone from England to Australia, and two years later Amelia Earhart crossed the Atlantic from America. At a time in history when women were only just winning social and political rights, flying presented to them an even greater challenge than it did to men. The years 1929-1939 were the decade of the lady pilot. Teenage fictional heroines drove fast cars, speed boats and aeroplanes. Air racing had an enthusiastic following as it combined the thrills and dangers of the early technological era.

The Second World War

By 1939 the romantic era of aviation was drawing to a a close. When war was declared in September that year, the Air Transport Auxiliary (ATA) was formed by the Royal Air Force. The first eight women were led by Pauline Gower. As time went by, the minimum 500 hours experience necessary for women to qualify for the ATA was lowered and more women were given test-flights and accepted. As pilots of the ATA they would ferry planes from factories to maintenance units and the RAF squadrons, either for training purposes or for active service. They would also transport dispatches and mail, medical supplies and VIPs. In the beginning they were not allowed to fly anything larger than Tiger Moths and similar light aircraft. Eventually, their ranks were to swell to a hundred; they piloted huge four-engined bombers and the first tempermental jets all over Britian as well as across the Channel to Europe in the last stages of the war.

In 1942 the first American woman came to share the danger, the arduous work and long hours.

From 1942 to 1944, almost two thousand women pilots left their civilian lives as students, secretaries, blackjack dealers and wives with husbands overseas to converge on Avenger Field, Sweetwater, Texas. There, the only all-female cadet air base in history, they slipped into ill-fitting men's GI flying suits and marched into the "Army Way" of life. Six months later, the Women's Airforce Pilots (WASPs) were ready to fly every airplane in America's air arsenal, from the colossal B-29 Superfortress to the lightning-fast P-51 Mustang Fighter. Over seventy of these air heroines were killed or injured flying for their country. They flew 70 different types of aircraft over a distance of 9 million miles. Despite their service, the WASPs were not officially recognized until 23 November 1977 when President Jimmy Carter signed veterans status for the Women's Airforce Service Pilots of World II. They were issued discharges to be presented to the Veterans Administration so that they could finally enjoy those benefits enjoyed by all their male counterparts.

Post World War II

Following World War II, women continued flying primarily in civilian aviation circles. The militaries of the world did not admit women to undergo pilot training until the mid seventies. The United States led the way. In 1973, the first eight female flight students began flight training. In 1974, Lt Barbara Rainey became the first woman naval aviator to gain her wings. She was later to loose her life in a mid-air collision in 1982 while instructing in a T-34. The Netherlands commenced military pilot training in 1978 and Nelly Speerstra became the first female combat pilot trainee within NATO. This was followed by Canada in 1979. Canada opened pilot training as a trial program. There were four initial trial candidates who commenced training in November 1979. In February 1981 three graduated to wings standard and went on to fly as instructors or transport pilots. There followed seven years of recruiting and training female pilot candidates until 1986 when the military concluded the trial, deeming it essentially to have been successful and viable. One year following, all restrictions to the employment of female pilots were lifted and fighters' tactical helicopter squadrons and shipborne anti-submarine warfare helicopter squadrons were opened to women. The first two women, Dee Brasseur and Jane Foster commenced basic fighter pilot training in June 1988 and completed transition training on the CF-18 in June 1989. These two pilots are currently employed on Operational Fighter Squadrons undergoing combat-ready training.

In over 100 years of aviation history, many women have made exceptional personal and professional sacrifices in pursuit of the privilege and right to fly. No doubt, future fledgling aviators owe much to those who have gone before and opened the hangar doors to new horizons for women in aviation.

Into The 1990's and Beyond

As of 1st April 1990, 8 countries are recruiting female military aircrew (although the United States do not recruit them in the Marine Corps, nor do the United Kingdom recruit them into the Royal Navy or the British Army). Of these, 5 countries - Belgium, Canada, the Netherlands, Norway and Spain have legislation which allows them to fly in combat. There are six countries who currently do not recruit female military aircrew at all. Currently the number of operational female aircrew in all countries totals approximately one thousand. This is summarized in the following table.

Title: Current status of recruiting and number of military pilots trained in NATO Airforces.

Country	Recruiting		Allowed in Combat	Approximate No. of Pilots
	Yes	No		
Belgium	1983		Yes	0
Canada	1979		Yes	19
Denmark		X		
France				2
Navy	1983			15
Airforce	1983			18
Army	1983			
Germany		X		
Greece		X		
Italy		X		
Netherlands	1978		Yes	16
				2
Norway	1982		Yes	
Portugal		X		
Spain	1989		Yes	0
Turkey		X		
United Kingdom				
RAF	1989			0
Army		X		
Navy		X		
United States				
Army	1973			220
Navy	1973			212
AirForce	1976			Approx. 500
Marine		X		

Objectives

My colleagues and I in the aeromedical panel (AMP) considered it was time to dispel some of the myths related to the female aviator. With the approval of the AGARD National Delegates Board and the Chairman of the AMP, we received the permission to organize a symposium on the principles topics -

- Operational experience of female pilots
- Selection and performance
- Anthropometry
- Aircrew personal equipment
- Physiological consideration

If you were one of the 116 people who attended the meeting, we hope that you enjoyed the meeting contents, if you only received the conference proceedings and there any outstanding questions either not addressed or answered, I would be pleased to hear from you. A letter or Fax 416 635-2104 to me at D.C.I.E.M. will receive a reply.

Acknowledgements

As programme chairman I would like to acknowledge a number of people who made major contributions to the great success of this meeting.

This symposium could not have been carried out without the assistance of Captain Jim Brady of the United States Navy and Colonel Paul Vandenbosch of the Belgium Air Force. They helped me originate the topics, the call and choice of papers and very ably co-chaired the meeting. I have also to thank Air Commodore John Ernsting, Mrs. Patricia Rothwell and Mrs. Cathy Sutton for their opinion and advice on the final programme before we went out for the call for papers. I have to thank Major John Winship and Mademoiselle Dany Michel at AGARD Headquarters for all their hard work in getting the pink forms out on time and collating all the camera ready papers so that there was no delay in distribution of the conference proceedings.

The three female operational pilots established the quality of speakers for the entire meeting and I would like to thank Commander Lynn Hutton, U.S.N., Major Dee Brasseur, Canadian Air Force and Lieutenant Mireille Winnubst from the Royal Netherlands Air Force for taking time off from their squadron duties to present their fascinating experiences. I would also like to thank all the remaining presenters for not only their quality of papers, but ensuring that they spoke within their prescribed time. We presented 28 papers in two days including questions and answers and stayed on time, a fine achievement.

This was my first experience at organizing an AGARD symposium. I did not realise how much paperwork was involved in the job. The majority of this fell on the shoulders of my very capable and efficient Administration Clerk Sergeant June Parris who already has a full time job. Not only did she type all five camera ready manuscripts for the Canadian papers in this conference proceedings, but also volunteered to type two additional ones which may not have met the deadline of going to press otherwise. We all owe her a vote of thanks.

Lastly I have to thank Major Dee Brasseur and Lieutenant Commander Blower for their assistance in helping me put together this brief history of women in aviation in which I have relied heavily on the books "The Sky's the Limit" by Wendy Boase and "Those Wonderful Women in Their Flying Machines" by Sally VanWagenen Keil.

THE INTEGRATION OF WOMEN INTO U.S. NAVY AIRCREW TRAINING AND SQUADRON ASSIGNMENTS

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SUMMARY

Aviation and military service are non-traditional career choices for women. Though obvious, the fact remains crucial to the success of integration programs. Much is written and said about the "average woman": her size, weight, strength, mental acuity, leadership, competitiveness, and drive to excel. But discussions on the "average woman" are erroneous; the average woman does not seek non-traditional career paths! The woman who seeks a non-traditional military career will be an intelligent, outspoken student of above-average ability; confident, gregarious, and competitive by nature; active and athletically inclined; and routinely found in leadership positions. This dynamic over-achiever personality does not fit statistical norms for a population wide "average woman". However, these attributes do fit military aviator candidate profiles; the reason for successful integration.

Cultural attitudes and biases are displaced by time. However with forethought and planning, the integration of women into naval aircrew training and squadron assignments can progress smoothly. This paper provides a planning outline which covers employment intentions, development of an accession model, flight training attrition, aviation retention, and addresses integration concerns and lessons learned.

INTRODUCTION

The integration of women into aircrew training and future squadron assignments will be facilitated by determination of employment expectations. Essentially you must honestly determine whether your women aviators will be used for public relations, or will they serve a functional role in support of your nation's strategic needs. National political goals, existing laws, and the cultural environment may create limiting factors on the type aircraft and aviation communities made available to women. Consideration of these factors develop military service employment expectations.

I can tell you that sexual physical differences are not a limiting factor. U.S. Navy experience has found no difference between the flight performance of men or women in any type aircraft, either high performance tactical jet, transport class or helicopter. Ironically, the average U.S. woman of about 5'6" (167cm) is anthropometrically better suited in size to the cramped cockpit arrangement of a tactical jet than the larger average male of 6' (182cm) or taller.

Once military aviation employment opportunities for women have been determined by type aircraft and aviation community, then attention must turn to developing a career path methodology. Conceptualization of appropriate military career paths based upon the necessary rotation between squadron and staff assignments, length of tours, increasing seniority and aviation experience combine to develop a proposed guideline or model for the ideally successful woman aviator.

Employment intentions must entail sufficient variety, depth, availability, and upward mobility to provide a challenging and rewarding career. This may appear patently obvious but failure to fully develop an appropriate methodology will adversely impact your administrative ability to accurately counsel the women on career decisions and ultimately effect their future retention. Given the austerity of most national military budgets this can otherwise become a prohibitively expensive mistake.

Once your needs and goals have been established, then the number and frequency of women accessions to your flight program can begin. By way of example, the U.S. Navy used the following basic formula to determine the number of women it should recruit into the naval aviation flight program: the total junior officer billets of squadrons to which women could be assigned, divided by two (to ensure no more than one half the squadron's junior pilots were women) with that number further divided by three. The initial naval aviation tour is three years long. In dividing by three we assumed that approximately one third of the squadron's initial assignment billets would be available on a yearly basis. This also assured sufficient variety of assignment possibilities available to newly designated women aviators, given their desires and capabilities. This same basic formula was subsequently applied to applicable squadron billets for middle grade and senior officers, thus further assuring appropriate upward mobility in the traditional military pyramidal hierarchial structure.

The original derivation provided 15 pilot openings per year. As the number and variety of available aviation commands expanded for women, the number of openings were consequently increased, still in keeping with the original formula. This year's accession goals are 52 women pilots out of a total naval training rate of 1079.

Earlier accessions did not account for flight training attrition. In actuality, the average attrition of women due to "academic" or "flight" failure is less than eight per cent. Total U.S. Navy pilot attrition for all reasons (physical disqualification, air sickness, etc.) has remained consistent at 20 per cent.[1]

The lower attrition rate for women can be attributed to the more selective screening process they receive due to the large number of women applicants screened for the proportionately smaller number of available program openings. Further, U.S. data could be considerably different from that discovered in other countries due to possible differences in academic background, psychological outlook, growth, and societal expectations.

Suffice to say, in the United States, women committed to aviation do extremely well. Perhaps of significant note: despite restrictive assignment policies based on U.S. combat exclusion laws and an aggressive hiring program by national commercial aviation companies, female naval aviation retention remains at 53 per cent, which is higher than the male naval aviation retention of 38 per cent. Additionally, of the 49 women who have left active duty naval flying (most for flying careers with major commercial airlines), 48 remain active participants in the "part time" selective naval reserve. When retention of the active duty and reserve participants are considered together, this allows a remarkable 96 per cent employment rate for women pilots. This makes women an excellent training investment![2]

One reason for this anomaly may be dual pilot/aviation career families. Many women aviators marry other aviators they meet in flight training or in their squadrons. The U.S. Navy has faced little assignment difficulty in area collocation of married service couples. As a matter of policy we do not assign a husband/wife aviator team to the same command. Should a couple marry while assigned to the same command, then one may be reassigned elsewhere in the area upon request of the Commanding Officer. However, most commands opt for retention until scheduled rotation dates.

A second, and more significant reason for higher retention among women pilots, is the increasing ratio of women helicopter pilots versus other pipeline communities. Woman helicopter pilot retention remains nearly twice as high (74 per cent) as that of jet or prop retention (both 46 per cent), and remains higher than the male helicopter retention of 55 per cent.[3] The accepted reason for this is quite simple: military helicopter pilots are not sought after by commercial airline companies, thus there is less civilian competition for those pilots' services.

Proportionately large numbers of women were not accessed into the U.S. Navy's helicopter pipeline communities until 1987. As these groups mature past obligated service requirements I would expect an even greater increase in women pilot retention.

FLIGHT TRAINING INTEGRATION

Integration of women into the flight training curricula should not be any different than for men. Candidate selection criteria based on medical condition, flight and mechanical aptitude test scores, and physical characteristic standards such as maximum-minimum height/weight remained unchanged. The one area the U.S. Navy reevaluated upon the introduction of women was the concept of physical conditioning versus strength.

Early classes of women demonstrated an inability to successfully pass mandatory male strength criteria such as pushup and pullup/chinup exercises. A reevaluation of successful flight performance dictated a more realistic and useful emphasis on endurance, agility, and above average physical conditioning. As such, U.S. Navy preflight physical standards currently entail a determination of these factors based upon successful performance on a 1.5 mile cross-country run and on a timed obstacle course run.

All other aspects of flight training remained unchanged. Women display an identical spectrum of ability in all phases, from academics to flight aptitude, inclusive of high-gee maneuvers, precision acrobatics, instrument flight procedures, formation flight, air-to-air and air-to-ground weapons training, and aircraft carrier landing ability.

The approach taken by U.S. Navy flight instructors to initial classes of women students saw a variety of responses, generally predicated by the instructor's background

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[1] Male attrition remains consistent at 9 %. In the categories of Flight and Academic failure, men and women fail with identical ratios: two-thirds for flight performance, one third for academic performance.

[2] Active duty attrition includes three flight deaths, none attributed to pilot error. Active duty resignation rate, less the flight related mishaps, would increase retention to 56 %.

[3] Comparative analysis of women's retention by community type through minimum service obligation presently lacks predictive validity due to the smaller statistical base.

and beliefs. Many instructors were belligerent or overbearing, seeking failure at every turn; some were intimidated or supportive, finding excessive success in the most routine evolution.

Since procedurally a student is rotated through a variety of instructors, this extreme psychological divergence in instructor attitude placed an undue stressor on the women in an already systemically stressful environment. With exposure and experience however, instructors came to realize, perhaps ironically, that men and women are more alike than different. As a result, this situation is far less likely today, especially with many women serving as flight instructors.

SQUADRON INTEGRATION

As might be expected, the same scenario of personalities confronted newly designated women on arrival to their first squadron assignments. Having survived the attitudinal extremes of approval/disapproval and approbation/condemnation of flight school instructors and peers, and perhaps through their own tenacity, these women pioneers succeeded in overcoming initial adversity.

Factors which decidedly lead to successful integration were twofold. Firstly, women were assigned to commands based upon their class standing and desires, thus obviating the belief that they, "got more than they earned." Secondly, and most important to eventual success, was "command climate"; a positive and supportive command climate directed by dedicated Commanding Officers. Many Commanding Officers held grave misgivings concerning the wisdom of integrating women into naval aviation. Yet despite their personal beliefs to the contrary, these professional naval officers and aviators insured success within their commands by discouraging intolerance and sexism and by treating the women just as they would any other junior officer.

In retrospect these pioneering Commanding Officers could have been assisted by informative and situational seminars, none of which were available at the time. Instead they had to contend with numerous myths of the day: "women cannot fly", "women are incapacitated one week each month", "women lack the necessary aggression to be good military pilots", "women are moody and difficult to work with", "men will not work for a woman", and so forth. As it was, Commanding Officers had to unlearn these myths one by one, yet not betray their personal inexperience or misgivings to their subordinates.

Today, women naval aviators are pervasive throughout the Navy in the flight training command as instructors and students, as test pilot engineers in research and development, as adversary pilots, and as squadron Commanding Officers, aircraft carrier department heads, and of course junior squadron pilots. They are prone to the same idiocies and elements of greatness as their male contemporaries.

Ultimately time forms the greatest barrier. Time overcomes the attitudinal biases, myths, and fears created by unfamiliarity and the unknown. As more women are integrated into the program and establish contact, familiarity, and friendships; they create a positive and pervasive change.

U.S. NAVY LESSONS LEARNED

If it is your nation's intent to introduce women into its military aviation programs, I thought it might be helpful to provide not only the basic insights previously discussed but some "lessons learned" or "mistakes made" as well.

As mentioned earlier for example, it was erroneously believed that if women could not meet established (yet unscientifically supported) preflight physical requirements of a specified number of pushups, pullups/chinups, leaping height, and timed runs, then they would fail the "strenuous flight regime" and prove unable to extract themselves from a disabled aircraft. As a result, the first class of women were placed into a physical conditioning program with enforced physical training. The program was conducted on their own time concurrent with their flight syllabus.

Not only did the women fail to achieve any greater physical performance, but the extra training curricula adversely detracted from valuable time to study and prepare for scheduled syllabus flights. Of historical note: to date, two women have successfully ejected from tactical jets without benefit of any augmented physical training (one was in an inverse spin).

The obvious solution to this situation was to develop a meaningful and more accurately predictive physical evaluation program.

Another equally detracting area for women was the inevitable media attention and necessary program public relations. A great deal of interest was directed toward the first group of women, which drew unwanted attention to them and greatly increased the already systemic pressure to succeed. The time required for the women to participate in these events also detracted from the time available for their flight and ground school studies. Additionally, it instilled jealousy and bitterness among their male contemporaries who received no similar attention, thus further isolating the women from their peers and the necessary student support network of information exchange.

In so far as possible, seek to limit media attention. Realizing that some information exchange is necessary, try to incorporate male pilots as well to emphasize the flight training/squadron experience for both men and women.

Another area of concern should be insuring the women's pipeline training adequately supports the end result assignment. The U.S. Navy initially prohibited jet pipeline training to women as cost prohibitive, unnecessary, and not conducive to specified needs. Women subsequently selected for assignments to tactical jet aircraft went through the entire fixed-wing prop training pipeline then through a jet transition syllabus.

Later, this method was found inadequate, more costly, and a disservice to the women who lacked sufficient training for their subsequent assignments. The obvious solution, and the one now in force, is to send women through the appropriate distinctive training pipeline for jets, props, or helicopters based upon the end result community.

It is not only important to fully integrate the womens' training but to leave no portion of that curricula out. Otherwise, you expose the lesser trained women to unwarranted belittlement and ridicule by peers for their lack of training or experience. Further, you limit future assignment options because they lack certain training and acquired skills, particularly in the valuable instructor arena.

Numerous other issues arise from time to time such as the sizes of issued flight clothing, routine medications, and pregnancy. Suffice to say many women will fall into the physically smaller acceptance profile. Although within the same acceptable standards as men, these women tend to have smaller feet, hands, heads, and necks. Though rarely limited in functional cockpit performance, these women find themselves limited by flight clothing sizes. Sufficient consideration and planning to tailor and recontract with clothing manufacturers precludes this problem.

The routine use of medications such as birth control pills has no impact on performance in the cockpit. On the other hand, originally the subject of pregnancy was confusing since it is neither disease nor injury and at the time aeromedical information for this medical condition was nonexistent. Surprisingly, pregnancy while in an "active flying status" has been minimal. Whether by intentional consideration for their commands or by desire to handle pregnancy in an operationally less demanding environment, those women who decide to bear children generally also choose to do so when not in a flying status.

On the occasion of pregnancy while in an active flying status, the woman requests a waiver to continue flying. Approval is predicated on the flight surgeon's recommendation, the type aircraft the woman flies, and the type of flight environment.[1] Regardless, annual flight minimums still apply. Time lost from work and flying is little different from that experienced by men for frequent sports-related injuries. Needless to say, some women have opted to have children and continue to serve and fly on active duty. They display no different abilities or drain on their time than men with children.

In conclusion, women can fly airplanes. The U.S. Navy has found they perform safely, conscientiously, and with the appropriate aggression to make excellent military aviators. Their motivation and retention remain exceptionally high. Though operationally limited in their employment due to current U.S. laws, <u>women fill valid and operationally necessary billets which would otherwise be filled by men</u>. Staff assignment opportunities are equally shared with men and the career-path process through command of an aviation squadron parallels the traditional path.

Integration of women into flight training and squadron assignments is far less difficult than expected. Success is predicated on clear definition of employment intentions, meaningful and rewarding career paths, and a systemic commitment to provide the time to overcome attitudinal bias. <u>Women provide a valuable resource asset in a demographically declining male population</u>. More importantly, women often provide an entirely different insight and approach to problem-solving. And in war, every conceivable approach to problem-solving is valuable and should be considered; because you can guarantee if you have not thought of it -- your enemy will!

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[1]Tactical jet aircraft, which require 100 per cent oxygen, torso harness, and gee-suit, and carrier aviation are limiting factors as is the length of time the waiver is granted.

WOMEN AVIATORS

TYPE COMMUNITY	JET	PROP	HELO	TOTAL
Pilots Designated to date:	55	84	73	212
On Active Duty:	40	54	66	160
Active Duty Attrition:	15	30	7	52
Designated Naval Aviators 1985 (MSR)#	28	56	27	111
MSR Attrition:	15	30	7	52
MSR retention:	13	26	20	59
% Retention:	46%*	46%**	74%	53%
Male MSR Retention:	35%	33%	55%	38%

TYPES OF AIRCRAFT U.S. NAVY WOMEN ARE FLYING

JET	PROP	HELO
A-7	P-3	H-1
A-6	C-130	SH-2
A-4	C-2	H-3
A-3	C-12	CH-46
F-14		CH-53
S-3		
US-3		
CT-39		
C-9		

#MSR = Minimum Service Obligation for flight training.

* One flight death (MSR retention less death: 48%)
** Two flight deaths (MSR retention less deaths: 48%)

All data current to 01/31/90

A CANADIAN FEMALE CF-18 PILOT'S EXPERIENCE

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Summary

I was born into a military family in Pembroke, Ontario, however RCAF Station Foymount was home. My father was a Telecommunications Technician and my mother taught piano out of our home. Once my brother was born we were on the move to RCAF Station Mont Apica, Quebec. Here, at the tender age of five, I do recall a visit to a helicopter which dropped into the station. I remember being totally awed by it. I don't remember being terrified by the noise it made as my mother informed me I was.

There followed numerous relocations so that in 19 years I managed to be a resident of 9 of my country's 10 provinces, live in 15 different houses and attend 8 schools to complete 12 years of education. Although the constant change in schooling, cultures, climates, geography and friendships seemed at times traumatic, in retrospect, it provided an excellent educational opportunity. In particular it enabled the development of self-confidence, self direction and a significant command of interpersonal relating skills. Activities differed by location and season dictating participation in everything from ballet, tap dancing, figure skating, Girl Guides and Brownies to hockey, baseball, football, fishing, camping, skiing, tennis and track and field. I found the more traditional "girls" activities to be quite frankly, boring and much preferred the rough and tumble of the "boys world". Being possessed with a "big for my age" label, I was more than capable of holding my own in a little mans world until that disasterous event, puberty! Fortunately however, high school offered a fairly dynamic track and field program so I still had an avenue in which to compete. I recall one day in 1965, while watching Chipmunks do circuits and bumps at RCAF Station Centralia, thinking that boys were really lucky because they got to be pilots. Not until 15 years later would the thought cross my mind that I might be a pilot.

In 1971, I enrolled in university in the faculty of Education. It was my intention to become a high school physical education teacher and coach. No other stereotypical female occupation interested me. I felt very strongly that I needed to work in an area which provided me an outlet for my physical energies, coaching would provide the mental psychological challenges.

Playing on the college basketball team kept me in university despite a very strong urge to assert my independence from home. My parents urged me to investigate the option of continuing my education through the military Regular Officer Training Plan wherein the military would pay my university costs and on completion of my degree would owe 5 years service. To an 18 year old, this seemed tantamount to going to prison for 9 years. Although I did make application, was acceptable to the Military, the classification that I wanted, that of Physical Education & Recreation was not available to women.

Enrolled in the Military

Following a summer employed as Head lifeguard and instructor at the Base Pool, I was in a dilemma concerning my university education. A taste of money meant freedom and independence and I was determined to untie the apron strings. Having associated with many of the non-commissioned ranks on base I learned much about basic recruit training. It sounded like a challenging, exciting, yet secure way to take those first steps out of the maternal nest. So in the fall of 1972 I commenced my military career as an administrative clerk. I knew how to type, so it sounded like the job for me. My intentions were to serve only six months as I was engaged to marry a servicemember. I considered my enrolment as an opportunity to learn about military life while he was off taking his officer training. Well, I came to really enjoy the challenges of my training and the camaraderie of my fellow course-mates, so much so that I decided marriage would only cramp my style and called it off.

However, following 2 weeks on the job as an administrative clerk I was ready to call it quits. The job was not physically demanding, nor did routine typing and filing fulfill my desire for challenge. I was comtemplating release and an application to the Royal Canadian Mounted Police who had just opened up to recruit women. My father on the other hand encouraged me to make application for commissioning under the Officer Candidate Training Plan. This I did and was accepted to eventually become an Air Weapons Controller (AWC). Here finally was the mental challenge I was seeking.

This is where I first met with the male/female monster. After having been closed to women for 10 years, the job of Air Weapons Control had only recently been reopened. As the first woman on my crew I experienced the stares, the snide comments, the questioning of my abilities and purpose for wanting to be a member of such a previously male environment. The bonus was that women had at one time been AWC and several of my crew members had known, associated with, and worked with women over the years and some had even married them! Once I established my credibility as a competent controller and demonstrated that their crude language and bad jokes did not bother me, I was accepted.

There was still those individuals who refused to change their chauvanistic opinions, and on one or two occassions, managed to assert their male dominance and position to stall my professional career development. Undaunted, I stuck to my guns and managed to solicit sufficient support to press-on and

advance in rank, position and responsibility.

No doubt my employment as an AWC led to my eventual application to pilot training. I managed to attend the High Altitude Indoctrination Course which enabled me to ride in the back seat of jet aircraft. This I did at every opportunity, I felt that learning about what the fighter pilots had to do on my direction would make me a better controller.

Unquestionable as well, the more familiar pilot and controller became with each others requirements and restrictions, the better team they make. Having whetted my appetite for flying, I started lessons on a Cessna 172 through the USAF sponsored Duluth Aero Club. I managed to solo my 10th hour and thus was bitten by the airborne bug. As AWACs was coming on line with Tactical Air Command and the job of airborne weapons controller was seen as combat-thus restricting women, I contemplated release from the military to follow a flying career.

Fortunately the SWINTER trials - Study of Women in Non-Traditional Environments and Roles was initiated. The Canadian Military established trial employment of women in remote locations, with army field support units, navy support units and the airborne occupations of pilot, navigator and flight engineer; of course I applied immediately for pilot training and was fortunately accepted as a trial candidate despite some supposed physical shortcomings which should have prejudiced my acceptance. For example my right eye was 20/30 - and it is rumoured that anthropometrically something was too short.

Commencement of Flight Training

I commenced flying training on 8 November 1979 at No. 3 Canadian Forces Flying Training School at CFB Portage LaPrairie, Manitoba. We were the first four women to officially undergo military flying training and as such were hotly pursued by all facets of the media at each step of the way, commencing at the Aircrew Selection Center in Toronto and continuing to commencement of training Portage, end training Portage, Land and Sea Survival Training Edmonton and Comox, beginning of and end of Basic Jet Pilot training at Moose Jaw and on to our final flying assignments. This proved to be a major stress factor for the female candidates as well as our male course members who were often excluded as we were continously being singled out of the group for press requirements.

The female trainees were never briefed, counselled or directed on the ways and means of the media with their inherant habits of manipulating the spoken word. Nor were we informed of the military policies of the day with regards to female aircrew selection, training and employment policies should we succeed as aircrew. All these things we learned through trial and error and suffered the resultant personal frustrations and the criticisms of our fellow male course-mates.

Another isolating factor was the fact that we female aircrew candidates were out of our peer group - not only were we female, we were Captains, commissioned officers with proven employment records. Our course mates by and large were direct entry Officer Cadets or 2nd Lieutenants who were generally younger and less mature and for whom this was their first exposure to women in the military. We had not all attended Basic Officers Training together and, therefore, had not formed those friendship bonds and mutual respect common as a result of sharing this phase of training.

Completion of Basic Pilot Training

The successful completion of Basic Pilot training was followed by a major press conference. It was at this point that I believe we became somewhat aware of the significance of our first achievement and the potential ramifications of future accomplishments. One of our female course-mates did not successfully complete training and thus became a national failure "the one who didn't make it". From then on we were well aware that we could be national failures and that our progress was scrupulously being monitored. I personally dreaded the thought that my individual success, or failure may affect the future employment opportunities for generations of young Canadian women.

However, we persevered through the remainder of our training schedule. At each turn of events or change of venue came additional irritants which only succeeded in increasing the pressure, and decreasing morale. Out of Winter Bush survival training came accusations from our male colleagues that we women were receiving special treatment. Evidenced of course, by the fact that we discovered that none of us had remembered to pack shampoo, requested and received a minimal amount from the staff in order that we could wash our hair about half way through the seven days in the woods routine. Of note, the four female members have no group portraits of ourselves in the 4-day one-man phase of training.

Evidently some of our male counterparts had difficulty avoiding the urge to gossip and made the odd visit back and forth amongst themselves. Of course our popularity was further enhanced by the fact that our confidential course reports were handed out in class with the care of coupon brochures and I bore the brunt of the chiding when one of the men read over my shoulder that I was the best candidate on the course. Heaven forbid that a female might out survive "mister macho mountain man" fighter pilot to be.

Advanced Jet Training

As our training continued in Moose Jaw, so did the conflicts. I learned much later that there existed a degree of competiveness amongst the Flight Commanders at the School. First evidence came when I was the first of our course to achieve solo status having skipped two trips to do so. Course-mates were envious, instructors were critical, my flight commander defensive, and I felt robbed of a feeling of accomplishment.

However, we three women were bent on success and very much wanted to be integrated, therefore we continued our efforts to appease and appeal to our course-mates. These efforts came to an end during the airshow in June 1980. Since our course was required to be on duty throughout the day, we women thought it a good idea to set up a course headquarters wherein we could get out of the sun, enjoy hot dogs and hamburgers, sip refreshments and generally try to recover from the previous night's hangover. To this end

we organized and financed the operation. It appeared to be successful until after the closing of the airshow when too many refreshments were consumed. Several of the more aggressive male group leaders proceeded to verbally berate our presence, dissect our physical attributes, criticize our motives and generally, in no uncertain terms, express their contempt toward us. Previous to this confrontation we were relatively unaware that we were fat ugly dykes, looking for husbands, looking for national acclaim, trying to prove men weren't really all that great, or that we were just as good. At this juncture our attitudes changed immeasurably.

I would go as far as to say that we three women were completely opposed in our individual personalties. We would not ordinarily have been inclined to become each others friend or confidant. However, stripped of any sort of peer support group we formed our own. We effectively decided that we should in fact act in a manner befitting our rank and experience and not bend over backwards to gain acceptance. Hence forth, we did not make any attempts to mix, mingle or promote conversation with our male course-mates. In effect, we ignored them and concerned ourselves with our own individual training progress. Without the constant confrontations and criticisms, day to day operations became much more palatable.

The final inter-flight, in-course conflagration culminated in December that year. The posting block was released. Thus commenced the guessing game - who was going where to fly what? The block for the course graduating before us had included a posting to Challengers, one of our VIP executive jets. This was eliminated just prior to their graduation thus lending support to the rumour that it was being reserved for the women. A much sought after job created much more animosity. Fortunately our block did not have a Challenger posting and therein died the argument.

Wings Graduation

On Friday the 13th, 1981, following a four hour press session, we finally marched out onto the parade square to be presented that much coverted flying badge, our wings. A very special event indeed for all three of us as each was able to be presented their wings by a family member.

In retrospect, the whole process had been fraught with much anxiety and stress such that I was convinced that I personnally was very proud to receive my wings, however I would not have repeated the process even under the threat of court martial or death. That was to come much later in the program.

On the Monday following graduation, myself and six of my course-mates commenced training to become flying instructors. Somehow, something had changed over the course of the weekend. There was no more animosity.

My own feelings are that as a result of receiving their wings, the boys had somehow become men. Their fragile egos had been satisfied, and they no longer felt threatened by the success of a woman. I believe as well they came to realize that we had all gone through the same grind and met the same standards thus acknowledging that our achievements were in effect equal; and deserving of mutual respect. Finally a period of respite!

Instructing

Beginning as an instructor was relatively easy. Although I could perceive in some students some initial apprehension about having a woman as an instructor they soon disappeared. Other instructors were as well initially apprehensive. When I asked them who was interested in flying a proficiency trip I rarely found a taker. Finally one day one fellow couldn't think fast enough to come up with the usual excuses, for example, "No thanks, I have to do some administration on base or go home and feed the dog etc...", so away we went. One could almost hear the thoughts running through his mind - culminating in the conclusion that whether or not she can fly, I know how to so I can always take control."

The trip was a routine clearhood and traffic pattern exercise. Several manoeuvers I was able to perform better than my cohort and vice versa. We split the "solo time" equitably without discussion and enjoyed a bit of a "smooth" landing competition. On our walk back to the operations building I remember specifically his comment, "Well that was a fun trip! We'll have to do it again sometime." There after followed several takers on my offers to fly proficiency and at the end of the six months I felt accepted and respected as a competant equal, in a position to turn down offers because I had to do administration on base.

Many comical encounters followed over the next few years as I criss-crossed the country on routine training trips; embarrasing pauses when checking in with Air Traffic Controllers, ground servicing personnel approaching the male students with questions assuming that they were the aircraft captain; stares, glares, finger pointing and whispers when moving about airport terminals and cafeterias.

Follow-On Employment

Following my tour as an instructor, I moved to the Canadian Forces Language School in Ottawa where I started French Language training. Unfortunately, four months short of the end, I was removed from course and given the job of respresenting the airforce perpective on the newly formed CHARTER TASK FORCE. It was mandated as a result of our recently passed Canadian Charter of Rights that the military review its employment policies and where contrary to the intent of the Charter, it had to be reviewed and revised accordingly. Many hours of research later, I finally understood the history of how I was able to become a pilot in the military. Doubly rewarding was the opportunity to influence the future direction of female pilot opportunities. The hint of fighter pilot training was in the air.

In December 1986 I moved to Cold Lake, Alberta where I assumed the position of T-33 Flight Commander of the Base Flight. Essentially I managed 12 aircraft and 8 pilots in accomplishing 3220 hours yearly flying of a number of diverse and varied mission types including air-to-air gunnery banner towing;

simulated air-to-ground training in support of forward air controllers in the army; North American Defence exercises as both target aircraft and radar equipment calibration aids; and a host of other utility support roles.

Historically, the Base Flight was manned by senior pilots and operated rather successfully based on their years of experience. However, the recent trends in decreased experience levels in our pilots, created a demanding supervisory challenge.

Redirecting this operation and bringing it more in line with its operational purpose was not easy. The young pilots resisted the change towards accountability for their actions and responsible unit resource management. With current budgetary restraints, no longer were they able to take a jet away on "cross country training". Acceptance was difficult because playing the heavy hand is not the popular way to gain friends. However, over time and with experience, they came to realize and accept their responsibilities.

Fighters

I had fully expected to remain in that position for three years; however, in November, 1987 my career manager offered me the opportunity I'd been waiting for - that of starting fighter pilot training in June 1988. Although I had been involved in the decision to recommend that women be allowed to fly fighters, I never expected to see this happen during my career. The offer to do so at 35 years old was both exhilarating and terrifying. Once again, I was about to expose myself to national scrutiny and that age old man/female monster. Amazingly and most important for nations just starting out with female pilots, I found that ten years had made a tremendous difference in attitudes towards female pilots.

Our years of flying experience and reputations for competancy preceeded us. We had one of the most cohesive courses ever to undergo fighter pilot training, resulting in the first 100% pass rate in years. Many of our course-mates we had previously worked with as instructors and many of the younger members were there as a result of our efforts in that capacity. Everything in the first six months of Basic Fighter Training was very pleasurable, There was much to learn and seemingly never enough hours in the day to learn it. The flying was challenging and rewarding. With the exception of a press conference three weeks into our training, we were sheltered from the interference and allowed to concentrate on the job at hand. On December 15, 1988, Capt Jane Foster and I became the first two women to graduate as fighter pilots in the Canadian Airforce. However, our fledgling wings were still very wet as we went on to six months training on the CF18. Here we finally were on the last previously hitherto virgin territory of the real world of fighters. And yes, the monster was alive and well and was to rear its ugly head ever so subtly in a last ditch gallant protesting fashion.

By and large the instructors were tolerant and very civil. One exchange officer was a different case. Within the first few weeks of the course I remarked to Capt Foster to take note that I said he would not fly with us. And although there were times when his name appeared opposite one of ours on the scheduling board, miraculously it was changed. He only flew against us as the bandit whose job it was to shoot down poor unsuspecting students. I can honestly say that to date my most memorable experience as a fledging fighter pilot was the day that this certain pilot shot down my instructor yet failed to put his female winger out of action.

An Operational Fighter Squadron

At the end of the day, 16 June 1989, I was a graduated CF18 fighter pilot onward bound to start combat-ready-training with the 416 Rapid Reactor Squadron based in Cold Lake, Alberta.

After completing one half of the required number of missions and 3 weeks of in-theatre European training, by a cruel paradox, I was resticted to non-heavy G flying due to a long standing ulnar nerve problem in my left elbow.

Presently, I am grounded and anxiously awaiting return to full time flying status following what I hope will have been the last of three operations performed in an attempt to resolve the problem.

In The End - Lessons Learned

So much has happened throughout my first ten years flying, that it is virtually impossible to record every minute detail. Some thoughts and feelings were transient as they emerged and subsided through the changes enroute to the finale. Others are more permanent and will remain with me for life.

I believe many lessons have been learned along the way and from a non-scientific personal perspective, I will attempt to summarize those which I believe are essential to the successful integration of women into the military flying business.

Good recruiting, selection and training are the essentials of success. Physical ability is particularly important as women must be recognized by their males counterparts as capable of holding their own throughout all phases of training. Selection processes must include investigation of a womans previous interests, activities and motives for wanting to fly. I feel that I can unequivocably state that a young woman who has only ever experienced the traditional female upbringing will not be a successful military pilot. On the other hand, those women raised amongst a family of brothers, who have enjoyed the typical tomboy activities and therein been exposed to the rough and tumble competitive male environment will in all likelihood be significantly more successful in their endeavours.

Once you have selected and recruited your female trainees, the next step is probably the most difficult and presents the most challenge on the road to success. Training, from day one to the end must be absolutely equitable. Supervisors must be ever aware to ensure that, neither they nor, their instructor staff compromising the standards of the system to accomodate females. Nor must they be overly critical or expectant of the female trainees. As difficult a task as it sounds, one must view trainees as a genderless

resource and treat each and every one on an individual basis, selecting whatever teaching method is necessary to enable the trainee to achieve the objective. Leadership sets the example with regards to acceptance and integration. If senior officers are verbally resistant to change, then subordinates only carry on the echo. If they perceive the mood to be one of favouring and supporting change, then this too will be reflected.

Shield female trainees from undue stress caused by public interest. In other words, wherever and whenever possible minimize media intrusions into the routine training process. This will prevent a lot of undue worries and enhance course integration. If media attention is unavoidable, ensure it includes the men who are training alongside the women. They will not feel left out and the country will not be left wondering how it is really going.

Do not delay inclusion of women trainees until you have large numbers. Realistically looking forward to their future prospective employment, women will be required to work in a predominantly male environment. Sheltering in groups will give you no indication of how the individual will perform in the real world. To be accepted as "one of the guys" is the ultimate objective and ultimate compliment. It essentially means that you have successfully made it. It means that your male peers no longer consciously consider you a female but, as a fellow pilot who just happens to be a woman. Your final success as a pilot will come as a result of acceptance, credibility and respect all of which are natural by-products of job competancy and interpersonal communicative skills.

THE SELECTION, TRAINING AND OPERATIONAL WORK OF FEMALE HELICOPTER PILOTS IN THE ROYAL NETHERLANDS AIR FORCE

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(A) Introduction

In 1976 it was decided in the Netherlands to allow women into allmost all functions within our armed forces, which included the flying occupation. Being one of the few female helicopter pilots of the 298 squadron for two years now, I will highlight some of the practical problems female helicopter pilots in the R.N.L.A.F. were (and still are) faced with.

Presently there are only 9 female helicopter pilots in the Netherlands Air Force; one female transport plane pilot; and one female jet aircraft pilot.

As I am relatively unfamiliar with the last two categories, I will focus solely on the experiences of myself, my 8 female colleagues and our few predecessors. Because of the low numbers, you will understand that this is a highly personal account.

(B) The Selection

In 1982, the first female helicopter pilot came through the selection system, which was not altered in any way for female candidates. As you can see in figure 1 we have a rather extensive selection procedure, which ends with several flights on a simulator and on the the Slingsby aircraft. These flights have been introduced only recently, in an attempt to decrease the number of students who fail flight school.

During the selection, the only equipment the Air Force has to supply its applicants, on a temporary basis, is the helmet to be used in the altitude chamber, which fits everybody. The separate accomodation during the days of tests are not a problem either. There are no remarks made on the subject of women, either by the fellow applicants or the Air Force people. You get the impression it is not such a big deal to be a female pilot.

(C) Training (figure 2)

(i) Introduction

There are two different categories of pilots in the Air Force: the pilots that studied at the Royal Military Academy, and the contract pilots. Those officers that finished the Academy understandably only have to do flight school, whereas the officers that will serve for a 8 year contract do both flight school and officers course. So far only one woman is an academy-pilot, so I will describe only the training of the contract pilots.

(ii) Equipment

At the Elementary Military Flight School a few problems with equipment can arise. I do not think women mind having to wear male long johns, or other typical male attire. Our normex underwear is without exception far too large (also for the men, by the way) so we sew it, to make it a better fit. Flight suits are nowadays available also in the very small sizes, so that they do not pose a problem anymore.

A problem that does exist is the glove-size. Some of my colleagues have exceptionally small hands. When I went to flight school, now 4 years ago, part of our training was at Fort Rucker, Alabama, where gloves were to be had in all sizes for everybody. However, back in the Netherlands no gloves of such a small size are available. We have been told repeatedly that they do not even exist. It makes us wonder what it was we wore in the United States then!

In general, women are not very fond of the combat/flying boots supplied by the R.N.L.A.F. Most of us are prone to blisters and Achilles tendon inflammation when wearing them for a long time at a stretch. Some colleagues, including myself, therefore buy American boots, which are slightly more comfortable. In the near future, however, our Armed Forces will get new boots that are supposed to be much improved, compared to the present ones.

A rather wise arrangement made by our Air Force. Every two years our women are given a certain amount of money to buy material that the Air Force does not have in supply. (like ladies shoes to go with our uniform, underwear, stockings, etc.)

(iii) The Instructors

When I applied for training, 4 years ago, there were only three women employed at the squadrons, the first one being operational only for three years, so to most of the instructors at that time, the idea of having flying women around was unusual.

They tended to ask funny questions: "How does it feel to be a woman among so many men? There were inconsistencies, for instance some instructors were very careful in reprimanding us on our flying skills and techniques, whereas they would plainly yell at the men. Some accused us of not working hard enough, because we did not, (cannot!) sweat in the same amounts and the same places as men! Others clearly showed their doubts about women in the profession.

However, the latest instructors all now have at their home squadron about 25 men also 2 to 4 women, and they know it works. They have planned flights with them, flown missions with them, have celebrated beer calls with them. To these people female students are not something strange anymore, because they are used to it.

A funny reason for occasional animosity occurring between men and women students, is having women flying better than men. I have witnessed two cases in which a male colleague became rather hostile towards his female colleague, because her notes exceeded his, and thereby she "defeated" him!

The instructors (non-pilots) of the officers course, is nowadays an integrated part of the flight school (whereas in my time quite different from the flight instructors.) During this course, I remember our supervisor told us on the first day we were there, that he was strongly opposed to women in the Air Force, and that he would encourage our failure. In his eyes, women did not function properly in ground operations, and therefore certainly would not fit in the air. There was definitely a negative response to our presence.

Although the women do not have any problems with the study-aspect of the military training at the officers course, the physical aspect is a different matter. Officially it is recognized that there are physical differences between men and women, like considerably less muscle tissue, smaller lungs, etc.

At officers course, no distinction is made. Women have to run, carry, climb and exercise to the same extent as their male counterparts. If different demands were made, e.g. on official sports tests, this would lead to grumbling among the male students about women being given special treatment. Not having a different standard for women, however, was not satisfactory either. First, the percentage of long lasting injuries is much higher among women than it is among the men, as the women have to perform on the edge of, or beyond their physical capabilities. Second, when women had trouble in keeping up with e.g. speed marches, or lifting things, this would sometimes lead to an excessive amount of impatience among the men. Thirdly, it is very frustrating for the women themselves, not being able to compete on an equal level with the men. It is at this phase that some of our future colleagues ventilate their irritation in a hostile attitude towards their female colleagues.

Another aspect of the training was the increased attention given to women. This was especially strong during the military training at Elementary Military Flight Training. You were always watched, noticed, and criticized. If a high ranked official visited the course, attention was often drawn to the women. We were asked to do interviews for radio and magazines which excluded the men. A matter that understandably annoyed them, an annoyance that of course was vented on us women.

At debriefings of e.g. several days lasting exercises, everything the girls did, had been seen and was commented upon, barely half of what the men did was noticed. This applies to both the positive and negative aspects. I can very easily imagine why some of our colleagues got jealous.

All in all, in some women this leads to very negative attitude to the officers course. So far all my older female colleagues agree, that if they had known of the consequences beforehand, they would have never considered joining the Air Force. I do know, though, from conversations with my latest female colleagues who have just finished the combined flight school/officers course, that these problems are decreasing rapidly. Women are obviously becoming a more common sight, and therefore more accepted.

(iv) Survival Training

We were also given one month of survival training. Our pilots are trained in survival and escape evasion techniques, based on the scenario of a crash near or behind enemy lines. This is a very realistic, practical and - moreover - individual course. I cannot say there is any difference made there between men or women, nor is there any need for one.

(v) Deelen

After the Elementary Military Flight Training, the students for the jet aircraft leave for Sheppard Air Force Base in the U.S.A. whereas the helicopter pilots continue their training in the Netherlands. The transition from fixed wing aircraft to rotary wing is made on the Alouette III helicopter, at Air Force Base Deelen.

Several courses are run there:
- the rotary wing transistion course
- a course in army/air force cooperation and navigation
- elementary tactics

A positive aspect of this transistion, is that it is done at 300 squadron, where also operational work is done. It is the first introduction to practical military aviation that the student will enter after the course. Our pilot, on completion of 2 1/2 years of training become operational.

An amusing aspect is that at several times during the training, commanders tend to give us girls some unasked for "fatherly" advice. Advice that is usually contradictory: "Do not forget you are a woman. You should behave as one. Keep your distance, do not let them turn you into one of the "buddies". Or: "Do keep in mind that you are working with and among men. Adapt yourself, do not become an outsider. Make sure you become one of the buddies."!

(C) THE FUNCTIONING OF WOMEN IN OPERATIONAL WORK

(i) Introduction

In the Netherlands, there are three operational helicopter squadrons, and one small Search and Rescue group. Two helicopter squadrons are based at Air Force Base Deelen (299 and 300 squadron) and one is based at Air Force Base Soesterberg (298 squadron).

Ever since 1985, every squadron, which generally consists of 25 - 30 pilots, has at least one female pilot.

As you can see in figure 3, this year we will reach an alltime high of 9 female pilots, in addition 5 more will finish their training within a little over one year from now.

The only new equipment supplied at the squadron, is the survival vest: it does not fit very well, but neither does it fit the men very well!

As for the acceptance at the operational squadron, I think the present women, certainly compared to our predecessors, have nothing to complain about. Initially there was considerable resentment of the men to this intrusion in their "men's world", and many a mean attempt was made to discredit these first women at the squadrons. They have had the tough job to smooth out most of the mainly social adaption problems and to prove they made it, not because they were "favoured" by almost every person in the entire Air Force, but because they could do their work at least as good as the men!

As a result we feel completely accepted at the squadrons at this time. Part of the acceptance probably is also due to the fact that no distinction is made at all, neither by our commanders, nor by the people that we are assigned to on a mission. As we do not have a clause in our Air Force that excludes women from combat functions, we do exactly the same work as our male colleagues.

(ii) The Operational Work

The helicopter squadrons of the Royal Netherlands Air Force perform a variety of tasks in peacetime, the most common are:
- Reconaissance missions for the Army, at or near the front line
- transportation trips
- photo reconnaissance
- V.I.P./Royal flights
- artillery assistance
- training of army personnel
- emergency standby

Usually we operate from Air Force bases, where accomodation is no problem. Not at every squardon are there separate provisions for the women, but as long as the toilet and shower doors can be locked, we see no difficulty. On some exercises, the pilots stay in hotels, instead of on base. This usually leads to the single girl having to pay a higher price for her room than the men, who generally sleep with two in one room. If it is a 2 week exercise, the difference can become quite large. If you are lucky, the men decide to split the complete hotel costs evenly, and you pay an equal amount, but on some squadrons it is expensive to be the only girl in a group of men on exercise!

Two or three times a year the complete squadron moves into the field for usually a week long exercise. On that occasion the only extra provision needed for the women, is a "womens tent"", so both men and women have privacy. It took a long and tedious fight for the first woman at our squadron to have one extra tent taken along. Officially the Air Force is obliged to supply it, however, also officially, there is no way to obtain it! Unofficially a lot can be arranged, fortunately! Initially some men were strongly opposed to this "favouritism" of women, but as the number of women using the tent increased (we also have female drivers, navigators, administrators and car mechanics now) it is now accepted as normal. - Some years ago, there was also a rule that women were allowed to take a shower every day, when on exercise - the men were not. This rule has been extended to include men as well, removing thereby another point of friction. Also since last year, the armed forces are obliged to take chemical toilet with them on exercise, as the exercise areas were becoming too polluted through intensive use. This keeps us now from wandering as far from camp as possible, to find some quiet shrub! This much for the practical aspects of an exercise in the field.

As relatively unnoticed and accepted as we are at the squadron, we still appear to be a curiosity outside of it. The times that passengers refused to enter a helicopter flown by a woman, are more or less over, but foreigners particularly still have problems with us. For instance, last year a German Colonel confided to me, that he had never been afraid to fly before, but that now he was. After the flight, of course, he claimed he had lost his fear of flying with women, yet these allegations can be rather unpleasant. There is no reason to assume we women are less qualified than our male colleagues. We both passed the same flight school.

Especially on foreign bases, in countries like Germany and Belgium, where women are not a familiar sight in the armed forces, strange reactions can occur. One is stared at constantly. I can assure you that a 2 week stay on a German base is guaranteed to drive a female pilot crazy!

Another example of unusual reactions, is a Dutch jet-pilot, who choose to ignore me completely during and after the flight. It was not a problem for him to talk to my navigator, and thank him for the trip. After all, the navigator was male.

All in all, it can be a relief to return to "the guys" at the home base, and be one of the buddies again!

Some Commanders think the atmosphere at a squadron has improved considerably with women around. I guess it does curb the use of curse words, fights, excesses and vandalism at beercalls. Also in general women tend to be less boastful than the men. We do not have to go out of our way to prove ourselves so necessarily to our colleagues in the air. I like to think this quieter attitude might rub off a bit on the "macho men" at the squadron!

(iii) Relationships and Pregnancy

Understandably it is not unusual that relationships occur between pilots. So far this has, aside from several bouts of gossip, not lead to serious problems. Something that might become a problem particularly is pregnancy if it occurs. No concrete plans have yet been made for the occurance of such an event.

- How long can the woman continue to fly?
- What will be her function at the squadron when she gets grounded?
- Will she be able to continue working with the Air Force after the child's birth?
- If so what provisions will be made at the squadron to keep/feed the child?
- If there is no possibility to continue, for how long can she quit working? Is it maybe possible to temporarily interrupt the 8 year contract?
- What does the interruption do to the currency on the aircraft?

Most of us will think twice, before becoming the first one to try to sort this jungle out! We just do not know what will happen, if one of us gets pregnant. I am afraid, the Air Force does not know either!

CONCLUSION

The introduction of women in the armed forces will lead to practical problems, some of which (like the pregnancy case) will be a hard nut to crack. The initial adaption problems and the strain it puts on both men and women, might be even harder to solve.

In general, however, I think it is a correct assumption to say that as the number of women increases, the number of problems will decrease. The first women will have a very tough time, and I would suggest three of more women should start flight school together. Not only do they have a stronger voice when for example requesting provisions like a "women tent", they can also support each other better (men experience things in a different way than we do, and it can be a relief to talk to someone who understands!). Also attention is not centered on one person only, but on the group, which should make it easier to bear.

The best service to be done to newly introduced women, is to leave them alone, to avoid press coverage, keep them out of the center of attention, give them no privileges, and just let them do their job.

This talk is centered mainly on the problems of introducing female pilots in our Air Force. I would like to stress, though, that in the end the Air Force benefits from our arrival. In the past years our women have proved that it is possible to have men and women cooperate in a military flying environment. Taking into account the sometimes very open-hearted conversations I have had with male colleagues, I think it is a healthy development for both men and women to turn a rather unnatural male society into a mixed group of people. Both sexes can learn a lot about each other, certainly in this line of work.

Table 1

THE SELECTION PROCEDURE FOR PILOTS

First Day:

- Personality Tests
- Spatial Insight Tests
- Apparatus Tests (Pilot Motorics)
- Reaction Speed Test

Second Day:

- Interview with Selection-Psychologist
- Function Information

Third Day:

- Medical Examination

All of the above takes place at Air Force Base Gilze-Rijen

Fourth Day:

- Extensive X-Ray Photographs of back and neck vertebrae at Matthijsen Military Hospital in Utrecht

Fifth Day:

- Flight Medical Examination at National Air and Space Medicine Center in Soesterberg

Four Days:

- Automated Pilot Selection: Six "Flights" on a Flight Simulator at Air Force Base Gilze-Rijen

Four or Five Days:

- Practical Pilot Selection: Several Flights with the Slingsby Aircraft at Airfield Seppe.

Table 2

THE TRAINING OF DUTCH HELICOPTER PILOTS

Phase of the Training	Duration	Flighttime/Type
Elementary Military Flight Training	40 Weeks	40 Hours in Pilatus/PC-7
Advanced Flight Training	40 Weeks	90 Hours in Pilatus/PC-7
Helicopter Flight Training	15 Weeks	100 Hours in Alouette III
Air Navigator Training	7 Weeks	None as Pilot
Elementary Tactical Helicopter Training	10 weeks	75 Hours in Alouette III

Status upon completion: Limited Combat Ready Pilot

After flying at the Squadron for 18 months on either the Alouette II Helicopter or the Bolkow 105 Helicopter, the Pilot enters:

Advanced Tactical Helicopter Training	12 or 16 Weeks	70 Hours on Current Helicopter Type

Status Upon Completion: Fully Combat Ready.

Table 3

THE NUMBER OF FEMALE HELICOPTER PILOTS IN THE ROYAL NETHERLANDS AIR FORCE

Squadron: Year:	298 Squadron	299 Squadron	300 Squadron	Total R.N.L.A.F.
1982	-	-	-	-
1983	-	-	1	1
1984	1	-	1	2
1985	1	1	1	3
1986	2	2	1	5
1987	3	2	1	6
1988	4	2	2	8
1989	4	2	1	7
1990	4	4	1	9

LES FEMMES PILOTES = UNE QUESTION POUR LES HOMMES

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RESUME = La venue de femmes pilotes dans les forces aériennes, particulièrement dans les unités opérationnelles, suscite de multiples interrogations. Les questions qui se posent concernent en premier lieu les aspects anatomo-physiologiques. Ces aspects ont toute leur importance mais ils en recouvrent d'autres, d'ordre psychoaffectif, plus difficiles à formuler. Ceux-ci concernent par exemple la disponibilité psychoaffective de femmes, engagées dans des missions opérationnelles, et confrontées à l'éventualité de la maternité. Plus délicats à exprimer encore sont les aspects qui tiennent à la différence des sexes. Dans cette optique la venue de femmes pilotes se pose comme un problème pour les hommes, dans la mesure où elles pourraient par leur seule présence mettre en question des valeurs cultivées dans le registre des références viriles.

Dans nos sociétés occidentales, la ségrégation des hommes et des femmes tend à s'amenuiser. Désormais rien ne semble devoir s'opposer à l'avancée des femmes dans des activités traditionnellement masculines malgré des réticences qui ressemblent de plus en plus à des combats d'arrière garde. En ce qui concerne l'armée, les femmes ne sont plus cantonnées dans des rôles d'auxiliaires et les rencontrer en tenue de combat, monter la garde, assurant des responsabilités ne choque plus, même si la fonction guerrière reste identifiée au référent masculin.

Il persiste néanmoins des ilôts de résistance, pour lesquels la féminisation apparaît encore problématique. C'est le cas de l'aéronautique militaire et tout particulièrement de l'aviation de combat. Le thème de ce symposium en témoigne. Certes l'histoire de l'aéronautique a été marquée par des aviatrices célèbres. Il y eut même des femmes engagées dans des missions de guerre, mais, peu nombreuses, elles ne purent tenir leur rôle durablement. Les expériences de la seconde guerre mondiale ne dépassèrent pas la durée du conflit. De nos jours, les principales forces aériennes admettent des femmes pilotes, mais leur nombre est contingenté, et elles seraient écartées, à notre connaissance, des missions de combat.

Ces exemples et ces expériences n'ont donc pas suffi à établir la féminisation dans l'aéronautique militaire. Les arguments objectifs s'opposant à cette avancée des femmes ne manquent pas, mais la conviction avec laquelle ils sont développés, par des hommes, suggère des positions répondant à une autre logique. Il s'agit d'une logique affective, non rationnelle mais néanmoins puissante, ayant ses propres justifications.

Les arguments développés seraient ainsi au service de résistances psychosociales.

LES ARGUMENTS PHYSIOLOGIQUES

Pour tenter d'avancer dans la compréhension de ce qui est en jeu, revenons rapidement sur les arguments objectifs, ce que nous appellerons des préalables physiologiques, tenant à la constitution féminine.

Ils sont évidents. Sans les détailler nous rappellerons seulement qu'ils tiennent à des caractéristiques de la féminité concernant par exemple la force musculaire, la morphologie et la vie génitale. Ces aspects de la féminité amènent aux problèmes posés par la maternité, (les risques pour la future mère, le foetus, la question de la disponibilité professionnelle) et plus largement aux questions concernant la vie familiale.

Ils conduisent finalement à poser les problèmes sous l'angle des performances, objectivables tant qu'elles se situent dans le registre somatique mais bien plus difficiles à discuter lorsqu'on prétend évaluer le versant psychoaffectif des capacités.

Quoiqu'il en soit de la pertinence des questions d'ordre physiologique, elles vont être exposées dans un discours qui est aussi l'expression des opinions, des résonances affectives que ce sujet suscite. Voyons dès lors les sous-entendus que ces préalables, concernant ce qu'on pourrait appeler la féminité et la maternité, peuvent évoquer.

LA MATERNITE

Pour commencer avec la maternité, la question de l'antinomie avec le pilotage n'est pas seulement celle de la physiologie ou de la disponibilité opérationnelle, mais aussi de la disponibilité psychoaffective.

N'y aurait-il pas là des éléments inconciliables ? Le travail psychoaffectif à l'oeuvre dans la grossesse pour donner la vie parait peu compatible avec la pugnacité nécessaire dans la mission de pilote de combat marquée à l'extrême dans une des éventualités de

cette mission : donner la mort. Les femmes qui désireraient en être devraient-elles renoncer à la maternité, s'amputer d'une partie d'elles-mêmes ? Cela est concevable pour certaines mais alors, qu'en serait-il des vicissitudes et aléas qui pourraient suivre un tel renoncement ?

Cette question de la maternité conduit aussi à envisager l'éventualité d'une naissance. Les femmes occupées à la fonction maternelle ne disposeraient vraisemblablement plus de la disponibilité psychique nécessaire à l'activité opérationnelle de pilote de combat. Les troubles de l'adaptation ne sont pas rares chez des hommes pilotes de chasse à la suite d'une paternité, on peut supposer que ces difficultés seraient encore plus fréquentes chez des femmes pilotes.

Les réflexions qui se développent ainsi concordent avec un ordre qui s'est institué, depuis les origines, à savoir que les femmes n'ont pas à être exposées, comme combattantes, aux risques de la guerre.

Il y a donc là toute une série de raisons objectives mais aussi d'autres, plus difficiles à formuler, exprimées comme en filigrane, alimentant les résistances, radicalisant les prises de position.

Les questions ne vont d'ailleurs pas tenir aux seules caractéristiques intrinsèques d'un sexe (en l'occurrence les femmes), de ses capacités, de ses limites, (comme dans le cas de la maternité). C'est aussi le problème de la différence des sexes qui va se poser de façon insistante dans ces circonstances. C'est ce que nous allons évoquer avec l'autre aspect que nous avons annoncé : la féminité.

LA FEMINITE

Elle ne concerne ici que les aspects de la constitution anatomo-physiologique féminine, qui soulèvent des problèmes pour l'adaptation aux conditions, aux contraintes du travail aérien. On peut penser néanmoins que les obstacles ne sont pas redhibitoires, que des aménagements sont possibles.

Reste alors la question sous-jacente de la compatibilité de la disposition psycho-affective des femmes avec le pilotage de combat. A la différence de la question liée à la maternité, le terrain est ici moins sûr pour ceux qui argumentent sur les capacités des femmes. Si les caractéristiques psychiques prêtées aux pilotes de combat sont identifiées au sexe masculin, cela ne veut pas dire que des femmes ne puissent les posséder. Ces qualités ne dépendent pas, en effet, exclusivement d'un substratum biologique spécifique d'un sexe. Comme le suggérait une femme pilote, avoir les attributs d'une femme, et s'identifier à son sexe, ne veut pas dire qu'on manquerait de ce qu'il faut pour tenir un rôle dévolu habituellement aux hommes.

Dès lors pourquoi pas des femmes dans l'aviation de combat, dans la mesure où elles en feraient la candidature? L'histoire nous montre de ces figures de femmes ayant joué un rôle de premier plan, traditionnellement masculin, sans se départir de leur féminité. Nous évoquions les femmes pilotes ayant participé au dernier conflit mondial. Mais, justement, c'était pour noter que leur nombre était limité, qu'elles furent renvoyées à la vie civile après la guerre malgré leur valeur opérationnelle et leurs états de service. Certaines étaient intégrées aux hommes, plutôt isolées, comme moulées dans les stéréotypes masculins ; la plupart semblent avoir été regroupées, à part, dans des unités spéciales.

Cette ségrégation donne à penser qu'il fallait les protéger des hommes, à moins que ce ne soit les hommes qu'il ait fallu préserver.

Au bout du compte les prises de position, qui prennent parfois le ton de la misogynie, (*"L'aviation de combat, ce n'est pas un métier de femme"*, entend-t-on dire) déplacent le problème du côté des hommes.

Un des obstacles à la venue des femmes dans l'aviation de combat ne serait-il pas dans la difficulté pour les hommes pilotes à accepter cette présence ? Celle-ci ne risquerait-elle pas de remettre en question leur propre disposition affective, nécessaire à leur engagement professionnel ?

Pour prendre exemple dans le domaine du sport, qu'on imagine ce qui se passerait dans un match de rugby opposant des équipes mixtes ... Existe-t-il d'ailleurs une seule activité sportive à base de compétition et d'engagement physique qui accepte le mélange des hommes et des femmes sur le terrain ?

La mixité a toujours été redoutée des collectivités militaires. Ainsi la Marine s'est longtemps opposée à l'embarquement de membres d'équipage féminins. Tout récemment la marine de guerre britannique aurait ouvert ses portes aux femmes (nouvelle annoncée dans les médias) ; il semble que ce soit par nécessité du fait du manque d'effectif et en dépit des résistances du commandement craignant pour la discipline.

Mais la question de la discipline ne résume pas tout, particulièrement dans les unités opérationnelles des forces aériennes. Si ces hommes admettent difficilement l'intégration de femmes, il faut le relier à ce qu'ils vivent en commun. Le vol et le combat aérien impliquent un engagement personnel profond. L'énergie, de nature libidinale, qui est assignée à cet investissement ne peut guère concéder de partage.

La présence de femmes pilotes pourrait-elle bouleverser la cohésion du groupe, entamer par leur seule présence le potentiel d'efficacité des hommes en les détournant de leur but ?

Cette interrogation n'est pas la seule. Il ne s'agit pas que des *"faiblesses"* que pourraient avoir les pilotes pour des camarades féminines, mais aussi des failles et des zones d'ombre que ces femmes pourraient révéler, zones d'ombre recouvertes par l'idéal. C'est une atteinte aux valeurs fondamentales partagées dans le groupe qu'une femme pourrait incarner en toute innocence.

Autrement dit, les idéaux que les hommes pilotes cultivent nécessairement du côté des références viriles ne pourraient s'entretenir que dans une collectivité unisexuée, évitant les enjeux et les embûches de la différence des sexes.

CONCLUSION

En définitive, les questions soulevées par la venue des femmes dans les forces aériennes, particulièrement dans l'aviation de combat, dépassent les problèmes physiologiques. Sans rien perdre de leur importance ces aspects objectivables recouvrent d'autres questions, d'ordre psychoaffectif, plus obscures et difficiles à formuler.

Ces aspects tiennent à la différence des sexes, non seulement dans ce qui les singularise mais aussi dans la façon dont les sujets s'identifient à leur propre sexe et se situent vis-à-vis du sexe opposé. Examinée sous cet angle, la venue des femmes dans l'aviation se pose comme un problème pour les hommes. Alors que dans beaucoup d'activités humaines la participation égalitaire des hommes et des femmes se révèle positive et la différence, reconnue, joue comme un facteur stimulant, il n'en va peut-être pas de même dans des milieux très identifiés aux valeurs d'un seul sexe, structuré pour des activités opérationnelles impliquant un risque vital. Tel est le sens, semble-t-il, des résistances observées.

Ces réflexions ne nous amènent pas à prendre parti dans un débat sur l'opportunité d'admettre des femmes dans l'aviation militaire, mais à distinguer les différents ordres de questions qui sont soulevées, en attirant l'attention sur les aspects psychoaffectifs qu'évoquent cette perspective.

COMPARISON OF MALE AND FEMALE USAF PILOT CANDIDATES

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SUMMARY

Female Air Force pilot candidates were compared to male candidates in terms of factors related to pilot training performance. The factors examined included selection test scores, background measures such as college academic performance and major, and ratings from a college military training program. Successful candidates of both sexes, compared to less successful candidates, had higher ratings and test scores, and also a higher percentage of technical majors and licensed private pilots. The data were analyzed for predictive equity or whether the utility of the factors for prediction of flying training outcomes differed for females and males. The results of regression analyses indicated that the factors examined were equally useful for candidates of both sexes.

INTRODUCTION

Since 1955, the scores on the Pilot and Navigator-Technical composites of the Air Force Officer Qualifying Test (AFOQT) have been used by the Air Force when selecting individuals commissioned through Air Force Reserve Officer Training Corps (AFROTC) or Officer Training School (OTS) for Undergraduate Pilot Training (UPT). Those two composites have consistently been shown to be valid predictors of graduation from UPT (1, 2, 3).

In addition, other criteria have also been shown to be valid predictors of UPT graduation (4, 5). College technical degree, private pilot license (PPL), grade point average (GPA), and prior military service are used by both AFROTC and OTS when screening candidates for UPT. In addition, AFROTC includes in the screening process such information as the detachment commander's rating, a field training rating, and a Quality Index Score (QIS), a measure of officer aptitude (6).

Because the majority of individuals attending UPT are males, the validities of the selection criteria are essentially based on male data. However, approximately three percent of the UPT entrants commissioned through AFROTC and OTS (since 1976) are female (7). Little research to date has examined whether factors associated with UPT training outcomes are equally valid predictors for both male and female pilot candidates.

One of the more important characteristics for any test or measure used to aid a selection decision that involves different subpopulations, such as males and females, is that it exhibit predictive equity. Predictive equity, for purposes of the present discussion, is defined in a statistical sense. The presence of predictive equity indicates that the use of a common prediction equation does not produce systematic error in the prediction of the criterion for persons in different subgroups (8).

Lack of predictive equity can result in two problems. First, underprediction for members of a subgroup produces a lower computed probability of success at a given aptitude score compared with another subgroup. The practical effect is to screen out subgroup members who would have performed well on the criterion of interest. In terms of pilot training, candidates who might have performed well never enter training.

Second, overprediction for members of a subgroup produces a higher computed probability of success at a given aptitude score compared with another subgroup. The result is selection of subgroup members who are incorrectly predicted to do well but who fail. For UPT the latter problem results in high attrition and increased training costs to achieve the desired pilot production volume.

The predictive equity of selection factors for female pilots is of particular concern in the 1990s because of the increasing role of women in combat-related flying. Although women presently constitute a relative small percentage of the total pilot candidate pool, that proportion may increase in the future. Thus, it is important to understand how female candidates compare to their male counterparts and to examine whether the validity of pilot selection measures developed on male populations extends to female pilot candidates. Thus, the purpose of the present research was to examine for three samples the predictive equity of the AFOQT and of other measures (e.g. college data, previous flying experience) for selection both of males and females into Air Force pilot training.

METHOD

Sample

The background data sample consisted of 8,446 subjects (8,285 males and 161 females) commissioned through OTS and AFROTC who attended UPT from the years 1982 to 1987. The AFROTC subsample consisted of 6,213 subjects (6,166 males and 147 females) identified as being commissioned through AFROTC and having data on AFROTC-specific selection variables (i.e. Quality Index Score). For the AFOQT analyses, the selected subsample was constrained to subjects tested c Form O of the AFOQT, which represented a major revision from earlier forms in terms of ·he number of subtests and the derivation of composite scores. Thus, the AFOQT subsample consisted of 3,243 males and 59 females from both AFROTC and OTS commissioning sources.

Procedure

All of the data for this study came from archival data bases maintained by the Air Force Human Resources Laboratory (AFHRL).

Measures

Predictors. Background information included college major (coded one if a technical degree, zero otherwise), grade point average, and possession of a private pilot's license (coded one if yes, zero otherwise). Additional information on AFROTC candidates consisted of a rating by the AFROTC detachment commander; a rating from field training conducted between a candidate's sophomore and junior years in college; and a Quality Index Score, a weighted composite of subjective motivation measures and objective learning indicators (6). The test scores used from the AFOQT were the percentile scores on Form O of the Pilot and Navigator-Technical composites of the AFOQT, a paper-and-pencil, group-administered, multiple aptitude battery (9).

Criteria. The main criterion was training outcome in UPT (pass/fail). For the analysis of background factors and AFROTC variables, the fail category included candidates who attrited for a variety of reasons: flying training deficiency (FTD), fear of flying, medical factors, and self-initiated elimination. For the AFOQT analyses, the criterion was defined so as to include only FTD attrites and graduates for two reasons. First, the AFOQT was not designed to predict elimination for non-FTD reasons. Secondly, as all OTS female attrites in the sample were identified as FTD eliminations, the AFROTC female subsample and the OTS and AFROTC subsamples were also limited to include only FTD attrites to ensure valid comparisons.

Analytic Strategy

Mean differences between the sexes in predictor variables measured on an interval scale, such as GPA, were examined with t tests. Differences by sex in categorical predictor measures such as possession of a pilot's license were compared using a chi-square test. To test for bias effects, the general linear models (GLM) approach (10, 11) was used. The GLM approach can be used to test for two types of bias: level bias and slope bias. Level bias indicates that regression lines for different subgroups have the same slope but the intercepts are different. Evidence for level bias is that differences in predicted scores for members of subgroups with the same level of predictor score differ by the same amount for all levels of predictor score. Slope bias is present when the difference in predicted performance for subgroup members varies at different levels of predictor scores. For the background and AFROTC-specific measures, bias effects were tested for the variables as a set, as the issue of interest was whether the subjective use of the combination of variables had predictive equity. Each AFOQT composite score was separately tested for equity because the concern was whether each score, in and of itself, had predictive equity.

RESULTS

Background Variables and UPT Graduation

For the background variable sample, males had a significantly higher UPT graduation rate (.72) than did females (.62, $X^2 = 7.01$, $p < .01$). Descriptive statistics for the predictor variables are shown in Table 1. Inspection of these data indicated that, in comparison with the males, the females represented a higher proportion of pilot candidates with PPLs and technical degrees. The females also had a significantly higher GPA than the males. Mean GPAs for male and female UPT graduates and attrites are shown in Table 2. For both males and females, the graduate group had a higher average GPA ($p < .05$) than did the non-graduate group.

Table 1 Proportions and Means for Background Variables by Sex

Variable	Male	Female	Significance Tests
Private Pilot's License	.11 (.31) [4452]	.20 (.41) [64]	5.34[a] *
Technical Degree	.49 (.50) [8269]	.59 (.49) [160]	5.04[a] *
GPA	3.04 (.59) [7230]	3.29 (.48) [141]	4.99[b] **

Note. Standard deviations in parentheses. Sample size in brackets. Sample size varies due to missing data.
a. Chi-square test.
b. *t* test.
* $p < .05$
** $p < .01$

Table 2 Mean GPA by UPT Training Outcome and Sex

UPT Training Outcome	Male	Female
Graduate	3.07 (.59) [5159]	3.37 (.46) [87]
Attrite	2.97 (.59) [2071]	3.17 (.48) [54]

Note. Standard deviations in parentheses. Sample size in brackets. Sample size varies from total because of missing data.

The percentages of male and female UPT graduates with and without a technical degree are shown in Table 3. For both sexes, the group with a technical degree had a significantly higher graduation rate ($p < .01$). Data for the relationship between PPL and UPT graduation for males and females are shown in Table 4. For both males and females, the proportions of UPT graduates for PPLs versus non-PPLs were not significantly different.

Table 3 Percent of UPT Graduates by College Major and Sex

College Major	Male	Female
Technical	75.7 [3097]	72.3 [68]
Non-technical	68.2 [2848]	47.0 [31]

Note. Number of UPT graduates in brackets. Number of graduates differs from total number of graduates in sample because of missing data.

Table 6 Means for AFROTC-specific Variables by UPT Training Outcome and Sex

Variable	Male Graduate	Male Attrite	Female Graduate	Female Attrite
Quality Index Score				
	79.97	79.36	91.12	86.95
	(12.31)	(12.17)	(10.72)	(10.79)
	[3360]	[1730]	[70]	[56]
Commander's Rating				
	6.13	6.07	6.53	5.89
	(1.89)	(1.74)	(1.92)	(1.86)
	[2710]	[1511]	[62]	[44]
Field Training Rating				
	6.42	6.32	6.74	6.61
	(.66)	(.65)	(.44)	(.55)
	[2639]	[1405]	[43]	[38]

Note. Standard deviations in parentheses. Sample size in brackets. Higher numbers indicate higher quality. Sample size varies due to missing data.

An equity analysis for the AFROTC-specific variables was conducted similar to that conducted for the background variables. For the AFROTC subsample analyses, the full model consisted of three predictors (Quality Index Score, field training rating, and detachment commander's rating), sex, and three two-way interaction terms (sex by AFROTC-specific variable). The full model significantly predicted UPT graduation (R = .13, F[7, 2844] = 6.51, p < .0001). Elimination of the interaction terms did not significantly decrease the predictive utility of the model (R^2 change = .0001, F [3, 2844] = .08, NS). Thus, no evidence of slope bias was detected. Elimination of the sex term from the model also failed to produce evidence of a significant decrement (R^2 change = .0001, F [1, 2847] = 2.06, NS). Thus, no evidence for either level or slope bias was found for the AFROTC-specific predictors, indicating that the same prediction equation could be used for male and female AFROTC pilot candidates.

AFOQT Composites

The graduation rate for males in the AFOQT subsample was 79%, which was not significantly different from the AFOQT subsample female rate (69%, X^2 = 2.95, NS). Mean AFOQT Pilot and Navigator-Technical Composite scores by sex are shown in Table 7. The male sample had significantly higher average scores on both AFOQT composites than the females. The mean AFOQT test score by sex and UPT outcome (flying training deficiency attrites only) are shown in Table 8. For both sexes, UPT graduates scored significantly higher on the Pilot composite (p < .01) than FTD attrites. Analysis of mean Navigator-Technical composite scores revealed a similar pattern, although the difference between graduates and attrites was not significant for females, probably because of the small sample size.

Table 7 Mean AFOQT Composite Score by Sex

Variable	Male	Female	t test
AFOQT Pilot Composite	72.06	66.51	2.30 *
	(18.35)	(17.98)	
	[3243]	[59]	
AFOQT Navigator-Technical Composite	66.58	59.81	2.53 **
	(20.41)	(20.09)	
	[3243]	[59]	

Note. Standard deviations in parentheses. Sample size in brackets.

* p < .05
** p < .01

Table 4 Percent of UPT Graduates by Private Pilot's License (PPL) Status and Sex

PPL Status	Male	Female
PPL	69.6 [319]	62.7 [9]
Non-PPL	66.6 [2773]	69.2 [32]

Note. Number of UPT graduates in brackets. Number of graduates differs from total number of graduates in sample because of missing data.

Multiple regression analyses were conducted to test for bias effects of the three background measures, sex and UPT pass/fail. The analyses were conducted using only subjects with data on all background variables, which resulted in a sample of 62 females and 4,376 males. The full model consisted of seven predictors: three background variables (PPL, GPA, degree), sex, and three two-way interaction terms (sex by background variable). The full model was significantly predictive of UPT graduation (R = .12, F[7, 4430] = 9.70, $p < .0001$). Elimination of the sex by background variable interaction terms did not significantly decrease the predictive utility of the model (R^2 change = .0002, F [3, 4430] = .39, NS). Thus, no evidence of slope bias was detected for the three background variables. Further, elimination of the sex term from the model did not significantly decrease the model multiple correlation (R^2 change = .0005, F [1, 4433] = 2.22, NS). Therefore, no evidence of intercept bias was detected. For both males and females, GPA, technical degree and PPL manifested predictive equity for UPT pass/fail.

AFROTC Selection Variables

For the AFROTC subsample, the males had a significantly higher percent of graduates from UPT (67%) than the females (56%, X^2 = 6.85 $p < .01$). Descriptive statistics for the AFROTC-specific measures are shown in Table 5, as are significance tests for differences by sex in proportions and means for the three variables. Females received significantly higher average ratings on the Quality Index Score and in field training rating than did males. Males and females did not differ in terms of the detachment commander's rating.

Table 5 Means for AFROTC-specific Variables by Sex

Variable	Male	Female	Significance Tests
Quality Index Score	79.76 (12.27) [5090]	89.26 (10.91) [126]	8.62[b] **
Commander's Rating	6.11 (1.91) [4221]	6.26 (1.84) [106]	.84[b]
Field Training Rating	6.38 (.66) [4044]	6.68 (.50) [81]	4.01[b] **

Note. Standard deviations in parentheses. Sample size in brackets. Higher numbers indicate higher quality. Sample size varies due to missing data.

a. Chi-square test.
b. t test.
* $p < .05$
** $p < .01$

Mean predictor scores for UPT graduates and attrites by sex are shown in Table 6. For both males and females, the graduates received higher average detachment commander's ratings (males, NS; females, $p < .05$), higher average ratings in field training (males, $p < .01$; females, NS), and higher Quality Index Scores than did the UPT attrites (males, $p < .05$; females, $p < .01$).

Table 8 Mean AFOQT Composite Score by UPT Training Outcome and Sex

AFOQT Composite	Male		Female	
	Graduate	Attrite	Graduate	Attrite
Pilot				
	74.30	63.35	69.76	59.11
	(17.32)	(19.59)	(17.22)	(17.94)
	[2578]	[665]	[41]	[18]
Navigator-Technical				
	68.43	59.42	61.17	56.72
	(19.76)	(21.28)	(20.27)	(19.90)
	[2578]	[665]	[41]	[18]

Note. Standard deviations in parentheses. Sample size in brackets.

Separate regressions were conducted to test the equity of each AFOQT composite. For each analysis, the full model consisted of three predictor variables: the AFOQT composite, sex, and the product term. The product terms were removed to test for slope bias, whereas the sex term was removed to test for intercept bias.

For the AFOQT Pilot composite, the full model was significant (R^2 = .24, F[3, 3298] = 69.59, p < .0001). No evidence was found for either slope bias (R^2 change = .0001, F[1,3298] = .38, NS), or for intercept bias (R^2 change = .0005, F[1,3299] = 1.86, NS). The full model for the Navigator-Technical Composite was also significant (R^2 = .18, F[3, 3298] = 36.76, p < .0001). No evidence was found for either slope bias (R^2 change = .0001, F[1,3298] = .66, NS), or for intercept bias (R^2 change = .0006, F[1,3299] = 2.18, NS). Thus, both of the composites showed predictive equity for males and females, in terms of UPT graduation.

DISCUSSION

The results of this study indicate that male and female pilot candidates showed overall differences on average test scores, background factors, and AFROTC ratings prior to entry into training. However, those overall differences were not associated with inequity of prediction of UPT training outcome. With regard to the AFOQT, for example, females tended to score lower on the Pilot composite; however, a male and female with the same score on the Pilot composite would be expected to have the same predicted success in UPT. Similarly, for the background factors and AFROTC variables, a candidate with a given profile of background factors or AFROTC ratings had the same predicted success in UPT, regardless of sex. Thus, the set of background variables, the set of AFROTC-specific variables, and the two AFOQT composites each manifested predictive equity in terms of their relationships to UPT training outcome.

Note that the observation that male and female candidates differed on test scores and background factors does not necessarily lead to the conclusion that the male and female applicant populations differed as well. Any number of factors, such as the lack of career opportunity available to females because of their historical exclusion from fighter aircraft, may result in pre-selection differences in male and female applicant groups. As more opportunities open to women, the nature of the female applicant group may change. Thus, one direction for future research would be to examine whether the same pattern of differences between male and female predictor scores in the present sample is replicated in future samples.

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NAVAL AVIATION SELECTION TEST SCORES AND FEMALE AVIATOR PERFORMANCE

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SUMMARY

The majority of U.S. Navy pilots are white males. Of the 12,477 Navy pilots, only 225 (1.8%) are women. Navy women are prohibited from permanent assignment on ships or aircraft designated for potential combat missions. In this paper, we present data comparing female and male performance on aviation selection tests over the past five years. We also compare female and male student naval aviator performance in primary flight training and on a cognitive/psychomotor test battery. The data examined in this report uncovered some differences in aviation selection test scores as well as differences in cognitive/psychomotor performance, but we could not discover any corresponding effect of these variables on success in primary flight training.

INTRODUCTION

Women have been involved in aviation since 1784 when Madame Elizabeth Thible went aloft in a Montgolfier brothers balloon over Lyons, France. Many American women aviators became famous in the 1930s, Amelia Earhart perhaps being the most renowned. Jacqueline Cochran accompanied 25 American women to England at the start of World War II to fly with the British Air Transport Auxiliary. When the U.S. entered the war, she became head of the Women Airforce Service Pilots (WASP). These women flew noncombat missions in order to free men for combat assignment. From 1942, until the WASPs were disbanded in December 1944, these women aviators flew more than 70 different types of aircraft over a distance of 9 million miles.

In 1948, the U.S. Congress passed a law that prohibited women from serving in combat. Twenty-four years later, ADM Zumwalt, Chief of Naval Operations, announced that naval aviation training would be open to women. The first eight female flight students began flight training in 1973. In 1974, LT Barbara Rainey became the first woman naval aviator to receive her wings. She died tragically in 1982 in Pensacola, Florida, while flying a T-34 as an instructor pilot. In 1979, the first female Navy pilot qualified to land on an aircraft carrier.

Today, female Navy pilots fly helicopters, anti-submarine warfare patrol aircraft, and transport aircraft. They also fly jet aircraft such as the A-4, T-39, and EA-7s, but because of the 1948 law, they do not pilot the Navy's front-line fighter and attack aircraft such as the A-6E, F-14 and the F/A-18. Navy women are prohibited from permanent assignment on ships or aircraft designated for potential combat missions. In addition, the U.S. Marine Corps has no female pilots (1,2,3). The question of allowing women into combat is currently under debate in Congress.

PREVIOUS RESEARCH

We found surprisingly few references in the literature concerning female and male differences in flight training or fleet performance. We synopsize below those few references we did uncover.

In 1981, Morvant and Thrower (4) evaluated gender differences in U.S. Air Force undergraduate pilot training (UPT) performance. They examined four general areas of training: flying time, instructors, learning rate, and check ride scores. In addition to analyzing 197 items from student flight records, the authors interviewed instructors and supervisors associated with the students. The interview information supported the flight training data from the study demonstrating that women did not perform as well as men. Overall, female performance differed significantly from that of men, primarily in the formation phase of training. The authors hypothesized that the formation phase of UPT was the first time that male/female competition was clearly manifested.

In another U.S. Air Force study (6), male and female pilot-selectee flying performance was compared. The authors concluded that, overall, the commonalities in performance between the sexes far outweighed the differences. A number of variables provided strong support for the conclusion that men and women perform similarly in flight training. These factors included 1) similar performance on most pre-training measures, 2) equivalent graduation rates, 3) comparable flight training performance, and 4) similar student impressions of the flight training experience.

Brown and Dohme (5) studied female performance in the U.S. Army's Initial Entry Rotary Wing flight training program using matched and total majority control groups (male). They compared performance of males and females on several criteria: 1) academic grades by training phase, 2) overall grade, and 3) flight performance grades by phase of training. Other variables included age, educational level, Flight Aptitude Selection Test (FAST) scores, and source of entry. Comparisons between the gender groups resulted in no significant differences on the matching variables.

Compared with the total majority group, however, females had significantly lower FAST scores. The authors suggest that if FAST scores relate to performance in flight training, females might be expected to experience more difficulty in acquiring flight skills than would the "typical" student.

In a two-part experiment, McCloy (7) used equal numbers of males and females to assess the hypothesized utility of various time-sharing measures as indicators of performance in a general-purpose flight trainer. Although he found no significant gender differences in either single- or dual-task performance on a single-axis compensatory·tracker and a digit-cancellation reaction time task, males had a significantly higher performance level on the various simulator variables. The author concluded that it might be appropriate to utilize gender-based predictor equations when establishing training or selection criteria for male and female complex-task operators.

U.S. NAVY SELECTION TEST BATTERY

The Navy's current test battery for selection of aviation training candidates was developed during World War II. The original battery was a series of psychological and physiological tests developed by the Civil Aeronautical Authority and National Research Council that were in use by 1940. Out of approximately 40 different tests, 3 were originally selected: the Wonderlic Personnel Test, the Mechanical Comprehension Test, and the Biographical Inventory (BI).

Previously validated with civilian pilots, the BI was introduced as a selection device in 1942. In 1953, it was revalidated, and new items were introduced to distinguish between successful and unsuccessful flight students. In 1978, the BI continued to correlate significantly with the pass/attrite criterion. The present selection test battery, entitled the Academic Qualification Test/Flight Aptitude Rating (AQT/FAR), is a direct descendent of the World War II efforts.

The U.S. Navy and Marine Corps AQT/FAR paper-and-pencil test battery is the primary instrument of interest in our study. Table 1 briefly describes the four individual tests of the AQT/FAR as well as two composites of the basic four tests. The last revalidation of the battery was in 1971, although it is currently being revised. This revision may be in place within the next three years.

Table 1. U.S. Navy and Marine Corps Aviation Selection Tests

1. Academic Qualification Test (AQT)
   105 items, 60 min.
   - Quantitative ability
   - General intelligence
   - Verbal ability
   - Practical judgment and accuracy
   - Following directions

2. Mechanical Comprehension Test (MCT)
   75 items, 40 min.
   - Mechanical aptitude
   - Ability to perceive relationships and solve practical problems in mechanics

3. Spatial Apperception Test (SAT)
   34 items, 10 min.
   - Spatial orientation
   - Ability to perceive relationships from differing orientations

4. Biographical Inventory (BI)
   160 items, untimed
   - Personal history
   - Maturity, risk-taking behavior
   - Informal acquisition of aircraft knowledge

5. Flight Aptitude Rating (FAR)
   The FAR is composed of the MCT, SAT, and the BI. A FAR index is produced when scores from these three tests are combined.

6. Officer Aptitude Rating (OAR)
   The OAR is a composite of the AQT and MCT and is used primarily for general officer (e.g., Supply Corps) selection and classification.

METHODS

The results reported in this paper stem from the examination of three existing data bases. The first data base is maintained by the Naval Aerospace Medical Institute and contains all the selection test scores. We analyzed the scores of all the female applicants who took the six selection tests during the period from January

1984 to December 1989. The second data base we examined consisted of flight performance data from the three primary flight training squadrons located at NAS Whiting Field, Milton, Florida. Finally, we accessed our own internal data base containing information on female and male student naval aviators who took our cognitive/psychomotor test battery. These students had already passed the selection tests and medical criteria and had received from 8 to 14 weeks of military indoctrination before we tested them. We generally receive a representative sample of students for testing and have built up a data base of 21 females and 1,089 males. These 21 females therefore represent 1.9% of our total data base, which approximates the 1.8% of female pilots in the fleet.

For the most part we present means and standard deviations of test scores along with the sample size. For the selection test scores and the cognitive/psychomotor test battery we conducted a t-test to determine if there was a significant difference between the males and females.

RESULTS

Table 2 presents some background characteristics of the 100 females we studied concerning selection test performance. These 100 females represent all the female applicants who took the selection tests from January 1984 to December 1989. They averaged 22.2 years in age when they took the tests. The 102 males in the male sample represent a random sample from the same time period.

TABLE 2. Background Characteristics of the Female Sample

Civilian	44
Officer Candidate, Naval Academy	23
Officer Candidate, ROTC	19
Officer, U.S. Navy	1
Officer, U.S. Coast Guard	11
Enlisted, U.S. Navy	1
Other	1
High-school graduate	1
Two or more years of college	51
College graduate	43
Post-college graduate	5
White	96
Black	1
Other	3

Table 3 shows the means and standard deviations for the female and male samples on the six selection tests. The t value for the difference between the means is presented in the next-to-last column. Females scored higher on the Academic Qualification Test, but the males were higher on the other three selection tests. Given this fact, the males were naturally higher on the two composite scores, the FAR and the OAR. Especially striking is the large difference in the Mechanical Comprehension Test.

TABLE 3. Comparison of Female and Male Scores on the Navy Selection Test Battery

	Female			Male				
Test	Mean	SD	N	Mean	SD	N	t	Sig.
AQT	6.20	1.26	100	5.77	1.41	102	2.28	$p < .05$
MCT	5.62	3.13	100	11.24	3.04	102	-12.95	$p < .01$
SAT	12.12	2.48	100	12.78	3.23	102	-1.63	ns
BI	11.30	3.28	100	13.39	3.50	102	-4.33	$p < .01$
FAR	5.53	1.40	100	6.96	1.66	102	-6.61	$p < .01$
OAR	47.83	6.46	100	50.36	7.97	102	-2.48	$p < .05$

As mentioned previously, data in Tables 4 and 5 come from female subjects who had volunteered to participate in a performance-based test battery conducted in our laboratory over the past five years.

Table 4 compares means and standard deviations for flight grade and number of aircraft hours flown during primary flight training. These data are from the 20 female subjects and 962 male subjects in our data base who, after taking our tests, successfully completed primary flight training. The flight grade is exactly the same for the two groups. The number of aircraft hours flown is slightly higher for the females as compared to the males but is not statistically significant.

Table 4 also shows that 20 of the 21 females in our data base successfully completed primary flight training. Historically, about 90% of all candidates who enter primary flight training are successful. Our sample of males at 88.4% is very close to this historical average as is our sample of females. Therefore, women do not differ from men on this important measure of performance.

TABLE 4. Comparison of Female and Male Performance in Primary Flight Training

Variable	Female Mean	Female SD	Female N	Male Mean	Male SD	Male N
Flight grade	3.05	.03	20	3.05	.03	962
Hours flown	75.02	9.18	20	73.03	9.71	953
Prob. of pass	95.2%	20/21		88.4%	962/1088	

The data presented in Table 5 show the relative standing of females and males on a portion of our performance-based test battery. This battery was designed to assess cognitive, personality, and psychomotor skills neglected by the paper-and-pencil selection tests presented in Table 1. The CVT test is a visual and cognitive information processing task with the dependent variable being the number of correct answers to a series of visual presentations. The ADHT is a horizontal tracking task with a short-term memory task superimposed. The dependent variable is the number of correct answers to the memory task. The PMTDLT series of tests is designed to measure eye-hand psychomotor coordination when a secondary listening task is superimposed. The dependent variables listed in Table 5 for the PMTDLT series are tracking errors. In two of these six tests to measure general information processing and psychomotor skills the females performed significantly less well than the males.

TABLE 5. Comparison of Female and Male Performance on Several Cognitive/Psychomotor Tests

Test	Female Mean	Female SD	Female N	Male Mean	Male SD	Male N	t	Sig.
CVT	101.75	7.26	12	100.11	9.48	550	.60	ns
ADHT	69.74	12.35	13	65.67	17.46	501	.84	ns
PMTDLT4	4.24	.38	16	4.04	.28	695	2.86	$p < .01$
PMTDLT5	3.78	.38	16	3.62	.28	692	2.31	$p < .05$
PMTDLT6	4.66	.23	16	4.56	.22	689	1.82	ns
PMTDLT7	4.10	.24	15	4.00	.25	670	1.55	ns

DISCUSSION

We have presented data comparing females and males on selection tests, as well as data on female and male student naval aviators performance in primary flight training and on a cognitive/psychomotor test battery. There are gender differences apparent in three of the four selection tests studied as well as differences in eye-hand coordination skills in a tracking task.

Mitigating these results is the fact that when we analyzed test scores from our performance-based test battery to see how well they could predict primary flight training outcome, gender was not a significant variable (8). The source of commissioning and college major, for example, were much more important than whether the candidate was male or female.

Interestingly, the PMTDLT series of tests, where the females did less well, was found not to predict success in primary flight training, but the CVT and ADHT tests where the females scored as well as the males were predictive of success. Additionally, once candidates have been screened by the selection tests, these tests seem to play little further role in predicting success in the later stages of flight training.

One important question, not addressed in this paper, is whether qualified female applicants are being unfairly excluded by the selection tests (9). As in any test construction, the standardization sample is crucial and must adequately represent the population being evaluated by the test. Even though the present selection battery has been revalidated, the standardization sample remains problematic with regard to female applicants. This is also the case with biographical inventories. One cannot depend on the continued reliability of items without frequent (e.g., two-year) probes to test for continued effectiveness.

Since the last extensive revalidation of the selection tests, recruitment policy has undergone major shifts that reflect changes in the overall social structure of the country. Despite changes in policy, however, minorities appear especially under-

represented in the aviation community. Part of the reason for this may be in the aviation selection tests themselves. The original normative sample did not represent the population for which the test is now intended. Subsequent samples have also failed to represent the present recruitment population. In addition, many aspects of the aviation environment have changed since World War II, possibly affecting aviation specific criterion-related validity, although the battery has done well in meeting the criterion of pass/fail for primary flight training.

To summarize, although the data presented here indicated some differences in aviation selection test scores and cognitive performance between males and females, we could not discover any corresponding effect during primary flight training reflecting the influence of these variables.

Although there are well-documented anthropometric and strength differences between men and women, it appears that general cognitive and information processing skills needed to pilot present day aircraft are equally shared by both men and women. The cockpits of future military aircraft will rely more heavily upon decision support provided by machine intelligence. The key question then becomes, "How well can the pilot integrate his or her problem solving capabilities with the assistance available from machine intelligence?" We need additional research on possible gender differences when the pilot plays such a role in a network of linked intelligences.

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REFLEXIONS A PARTIR D'UNE PRATIQUE DE SELECTION DE PERSONNEL FEMININ CANDIDAT A UNE SPECIALITE VOLANTE.

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RESUME

L'entrée des femmes dans les armées est une aventure humaine passionnante qui se continue, dans l'Aéronavale française par l'accession des femmes à la spécialité de pilote d'aéronautique navale. Ce qui peut être vécu comme une véritable intrusion par les hommes faisant partie d'une institution militaire très masculine dans son fonctionnement et ses valeurs, se révèle être un objet d'études intéressant. En effet, les candidates à la spécialité de pilote semblent montrer une réelle spécificité et un déterminisme particulier dans leurs motivations. Par ailleurs, elles posent un problème au clinicien qui les reçoit et qui va investiguer leur candidature qui nous semble être basée sur une recherche de survalorisation féminine. Cette réalité particulière de ce type de candidature pose le problème de son appréhension globale par un clinicien masculin.

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L'expérience de 7 années dans le domaine de la sélection et le suivi psychologique du Personnel Navigant de l'Aéronautique Navale française nous ont permis de vous proposer quelques réflexions sur une pratique de sélection de personnel navigant féminin.

1. Position du problème.

Dans la Marine française, l'entrée du personnel féminin est relativement récente, tout au moins dans son aspect régulier. L'accession des femmes aux spécialités dites techniques remonte seulement à 1980. Les emplois de mécanicien, électronicien et d'electro-mécanicien d'aéronautique furent donc ouverts au personnel féminin dès cette période, bien que l'Etat-Major utilisa la méthode des quota pour respecter une prépondérance masculine des effectifs.

Depuis 1983, les femmes peuvent postuler à l'emploi de pilote d'aéronautique, uniquement dans le statut d'Officier de Réserve en Situation d'Activité (ORSA). Depuis cette date, de nombreuses candidates se sont présentées, mais seulement 2 pilotes féminins exercent leur profession dans l'Aéronavale, ce qui montre toute la difficulté de ce projet, qui est à l'origine de ces quelques réflexions. Dans la Marine, les pilotes féminins sont actuellement recrutés pour des missions de liaison, et ne servent donc qu'en escadrilles, les missions opérationnelles étant réservées aux hommes (1).

Depuis le décollage de Blanche STUART en 1910, première femme-pilote dans le monde, la situation vis-à-vis du pilotage dans l'aéronavale ne semble pas évidente pour les femmes. En effet, peu de femmes accèdent à la spécialité de pilote et elles correspondent à une certaine exception, bien que le personnel féminin actuel soit bien intégré et rende d'excellents services, au même titre que les hommes.

Comme on peut le voir, l'entrée des femmes-pilotes est donc une aventure en route, mais qui n'est pas encore passée dans les habitudes quant à sa diffusion. Mais il peut etre intéressant d'observer les candidates à un tel poste, de par l'image de la femme-pilote qu'elles véhiculent dans leur imaginaire.

2. Etude de quelques éléments statistiques.

Rappelons que dans la Marine Nationale, le seul statut militaire permettant aux femmes l'accession à la spécialité de pilote est celui d'Officier de Réserve en Situation d'Activité. Elle n'est donc pas ouverte au personnel non-Officier. Par ailleurs, l'Ecole Navale n'étant pas accessible au personnel féminin, il n'y a aucune candidature appartenant au statut d'Officier de Marine d'active.

Le phénomène des candidatures féminines pour la spécialité de pilote est peu développé dans la Marine, au sens statistique du terme, alors que de nombreuses femmes sollicitent d'autres spécialités. En effet, seulement 66 candidates se sont présentées à la sélection. 30 d'entre elles étaient déjà militaires. Cependant, peu de demandes ont été acceptées, puisque seulement 9 sujets ont suivi le cours jusqu'alors.

Actuellement, la marine compte 2 pilotes opérationnels (1 pilote de multi-moteurs et 1 pilote d'hélicoptères) et 2 futurs pilotes de multi-moteurs terminant actuellement leur formation. Elle a assisté à seulement 2 éliminations en école de début. Par ailleurs, elle a vu partir un autre pilote vers une autre armée. En effet, une candidate a réussi sa spécialisation "Hélicoptères" mais a préféré demander ensuite son changement d'armée pour l'Aviation Légère de l'Armée de Terre (A.L.A.T.), voulant suivre son mari qui avait également suivi une formation malchanceuse d'élève-pilote dans la Marine, et qui, éliminé, avait pu obtenir son changement d'armée. Deux postulantes sont en train de suivre leur formation d'Officier, mais n'ont pas encore commencé leur formation spécifique de pilote.

Le taux de sélection est donc de 13,64 % en ce qui concerne les élèves choisies parmi les candidates, en sachant que seulement 71 % d'entre elles étaient aptes médicalement lors de l'examen au Centre d'Expertises du Personnel Navigant de l'Aéronautique Navale (C.E.M.P.N.A.). Il faut noter qu'il est assez hétérogène, puisque voisin de 20 % pour le personnel militaire et n'atteignant pas 9 % en ce qui concerne les candidates civiles. Le personnel militaire, déjà connu, a donc plus de chances d'être retenu. Le taux d'utilisation des sujets ayant commencé leur formation n'est que de 60 % actuellement. Il faut observer que la réorientation des sujets éliminés est plus évidente en ce qui concerne le personnel militaire.

A ce sujet, il faut noter que les candidates civiles ayant échoué dans leur candidature pilote ne retentent plus leur chance, hormis quelques exceptions. Par contre, leurs homologues militaires représentent quelquefois leur candidature ou postulent pour d'autres emplois aéronautiques. 2 candidates sont devenues Officier-Contrôleur, tandis que 5 autres sont mécanicien de bord.

Pour résumer, la sélection des candidates à la spécialité de pilote d'aéronautique ne se fonde que sur de petits effectifs. Le taux de sélection semble important car il convient d'éliminer de nombreuses candidates aux motivations imprécises ou peu pertinentes, ou dont les aptitudes psychomotrices pour le pilotage sont médiocres ou insuffisantes. Cependant, on ne peut nier le fort désir de la plupart des candidates d'accéder à ce métier prestigieux qu'est celui de pilote. Sur ce point, les candidates affichent une demande beaucoup plus forte et assurée que la plupart des candidats du sexe masculin.

Une remarque est à mettre en évidence, avant de clore ce dossier statistique : l'institution assiste, actuellement, à une diminution des effectifs concernant les candidatures féminines pour la spécialité de pilote. Ce fait semble important pour l'interprétation que nous en ferons dans la suite de notre propos.

3. Approche psychométrique et clinique des candidates

Notre attention a vite été attirée par les spécificités psychométriques de nos candidates. En effet, tant au test de Szondi (2), qu'au M.M.P.I. (3) ou encore au C.P.I. (4), elles obtiennent des scores étonnamment masculins. Ces résultats sont très significatifs puisqu'ils dépassent en majorité deux écart-types dans un profil utilisant une échelle ortho-normée.

Cette observation est à rapprocher de leurs centres d'intérêts très masculins. Tous ces éléments seraient en faveur d'une spécificité de ce type de candidature devant obéir à un certain déterminisme.

En effet, les candidates à la spécialité de Pilote d'Aéronautique semblent appartenir à une certaine typologie. Elles manifestent, en effet, une forte détermination dans leur démarche. Animées d'une personnalité sthénique, active, elles aiment se dépenser dans des activités physiques. Elles ont d'ailleurs des centres d'intérêt plutôt masculins. Leurs protocoles psychométriques confirment

ce trait. Elles pratiquent souvent des sports actifs, voire violents, tels que les sports de combat. Certaines sont attirées par les sports mécaniques. On constate également un besoin de compétition, de dépassement. Elles ont en général un caractère franc, direct, un moindre sens des nuances, une démarche expansive, positive.

Si elles restent féminines dans leur manière de percevoir la réalité, leur présentation extérieure et leur réaction, elles se démarquent de l'image féminine traditionnellement en usage dans nos idéaux occidentaux. Elles refusent de se laisser enfermer dans un modèle rigide, manifestant soumission, passivité, douceur etc.

Elles se montrent indépendantes, autonomes, s'étant déjà réalisées sur le plan sexuel, et possédant une certaine expérience au niveau du vécu. Elles n'envisagent pas de fonder une vie familiale immédiatement, désirant se consacrer avant tout à leur vie professionnelle qu'elles jugent prioritaire et indispensable à leur propre épanouissement. Elles possèdent également de bonnes qualités sur le plan de l'accession aux responsabilités, et ne doutent que peu de leurs capacités. Elles savent s'imposer et se faire reconnaître, parmi leurs relations sociales.

Dans leur projet de devenir pilote, apparait l'idée d'une accession à un niveau élevé de réalisation professionnelle. Il faut dire que l'image du pilote d'avion est considérée comme étant l'un des métiers physiques des plus prestigieux. L'idée de maîtriser une machine en trois dimensions peut d'ailleurs être considérée comme le dépassement de ses propres capacités, reprenant à son compte, tout en le portant à son comble, le mythe d'Icare. Une certaine provocation implicite des attentes et devoirs de la femme dans notre société leur permet de poser leur candidature plus fermement.

Un troisième type de remarque peut être fait à ce sujet. Il concerne les imagos parentales et notamment l'image du père. L'image du père de la candidate est en général très puissante, très intériorisée, comme si elle correspondait à un modèle identificatoire. Le père est assez souvent un militaire, ou aurait voulu faire sa carrière dans l'armée. La fille semble courir sur les traces symboliques de son père, à la manière d'un garçon. L'idéal du père est transposé alors sur un projet professionnel puissant et fort : être pilote d'aéronautique. Dans cette optique la candidate se rapproche fortement du modèle de la candidature masculine. C'est d'ailleurs cette particularité qui est la plus intéressante car bouleversant le mode d'appréhension de l'homme qui va devoir, par métier, appréhender cette candidature pour donner son avis quant à sa pertinence et ses chances de réussite.

4. Réflexions sur l'appréhension de ce type de candidature

Une telle spécificité, telle qu'elle a été précédemment démontrée, pose le problème de son appréhension pour un clinicien masculin. En effet, ce dernier doit définir des critères cohérents de choix permettant de définir dans un lot de candidates, celle qui a de meilleures chances de réussite. Or ce type de motivations lui pose un problème dans sa *praxis* professionnelle.

Le pilote est reconnu traditionnellement comme attirant la convoitise féminine, de par ses qualités physiques, intellectuelles. Il semblerait que le même phénomène se produise chez la fille, désirant ainsi se mesurer fantasmatiquement à l'homme. Dans un autre ordre d'idée, il semblerait que le même mécanisme soit utilisé dans bon nombre de publicités, dont celles concernant les sous-vêtements masculins, portés par les femmes ("je lui ai tout piqué, même son caleçon" !). Cette image "dévorante" transparait dans nombre de manifestations médiatiques, véhiculées par la publicité. Après le jean unisex, le port de la cravate par la femme, intervient le vol du caleçon, jusqu'à présent connu comme étant un susbtitut intime exclusivement masculin.

La genèse de la motivation à devenir pilote d'avion semblerait, à notre avis, reposer au plan de l'inconscient, sur le désir de se mesurer à l'homme, de se battre avec son image de force et de supériorité. Le désir de devenir pilote militaire, comme lui, s'apparenterait à l'idée de le traquer dans un des derniers bastions réservés à l'idéal masculin, afin de le dépasser, de le maîtriser. Peut-être s'agit-il, par là, de régler son compte à l'image de la femme telle que l'instituent et l'obligent nos sociétés patriarcales. Le ressort du féminisme n'est-il pas le désir de reconnaissance de la particularité de la femme, et le rejet de son enfermement par l'homme dans des structures sociales, culturelles par trop figées.

Comment dans ce contexte, un homme peut-il accepter cette recherche de survalorisation féminine ? La question reste posée. Par ailleurs, sur le plan de la gestion à long terme du personnel féminin, il est vraisemblable que les

réalités spécifiques des femmes (cycles hormonaux, spécificité d'utilisation, maternité, éducation des enfants) dans leur réalité, comme dans leur représentation auprès des hommes, posent le problème de leur utilisation. C'est d'ailleurs sur ce terrain que la polémique est la plus engagée par les hommes qui n'acceptent pas que leur place symbolique dans l'armée soit prise par des femmes...

Il semble donc difficile d'éluder cette question qui reste un problème de fond retentissant sur tout le thème de la sélection du personnel féminin pour ce type d'emploi.

5. Quelques pistes de réponse.

L'analyse statistique des candidatures féminines montre nettement que le nombre de jeunes filles postulant pour pilote alors qu'elles sont encore dans le civil est en nette diminution. Il semblerait donc que cette soif de survalorisation par rapport à l'image de l'homme, dans notre société, s'éteigne quelque peu. Actuellement, les candidates examinées manifestent moins cette particularité, souhaitant avant tout s'exprimer et se réaliser dans un travail actif, passionnant et plein de responsabilités. La "conquête du dernier bastion masculin" semble donc s'estomper.

Il n'en reste pas moins vrai que les motivations féminines pour ce travail spécifique du pilote d'aéronautique restent, pour le clinicien masculin, une véritable interrogation de fond.

En effet, l'entrée des femmes dans l'armée avait bousculé autrefois les consciences. A notre époque, ce fait est acquis. Il est cependant permis de se poser la question de l'entrée des femmes dans une institution masculine qui porte de manière très marquée des valeurs et des idéaux masculins. La candidate doit alors accepter de porter en elle une "empreinte phallique", celle de l'institution qu'elle a choisi. Dans ce sens, les candidates n'ont pas fini d'étonner les hommes, dans leur recherche de leur propre réalisation.

Quoiqu'il en soit, l'entrée des femmes dans l'Aéronautique Navale française bouleverse des habitudes, mais manifeste clairement la capacité de l'Institution Militaire de s'adapter aux réalités sociales de notre temps.

NOTES

(1) - Deux types de formations sont en service dans l'Aéronavale: les flottilles utilisées pour les missions opérationnelles, et les escadrilles servant surtout pour le soutien et la formation.

(2) - M.M.P.I. : MINNESOTA MULTIPHASIC PERSONALITY INVENTORY
Questionnaire de personnalité pathologique construit par HATHAWAY et MACKINEY en 1945. L'échelle Mf apprécie les tendances vers la masculinité et la féminité d'une structure d'intérêt.

(3) - C.P.I. : CALIFORNIA PERSONALITY INVENTORY :
Inventaire de personnalité utilisé pour l'évaluation des caractéristiques de personnalité et des modes de relations interprofessionnelles qui concourent à l'adaptation sociale et à l'efficacité personnelle de l'individu. Construit par GOUGH en 1979.
L'échelle Fe évolue elle aussi la masculinité ou la féminité des intérêts.

(4) - Le test de SZONDI a été réalisé par Léopold SZONDI en 1947. Il s'agit d'un test de personnalité semi-projectif, basé sur l'épreuve de choix à partir d'un matériel de photographies. Il nécessite la compréhension préalable de la théorie personnelle de l'auteur mais apporte des éléments cliniques indiscutables.

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SEX DIFFERENCES CONCERNING PERFORMANCE AND PERSONALITY TRAITS OF APPLICANTS FOR HIGHLY QUALIFIED OPERATOR FUNCTIONS IN AVIATION

by

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SUMMARY

Today, in the West German civil aviation females apply for training as pilots as well as air traffic controllers. Female pilot applicants are still a minority of less than 10%. Representative data only exists in the area of air traffic control (ATC) where about 30-40% of all applicants are female. In the psychological selection of applicants for ATC training the rate of acceptance is significantly smaler for females than for males. Therefore sex differences were investigated in cognitive aptitudes as well as in aspects of personality. The results revealed clear deficiencies for the majority of female applicants in two basic operational aptitudes: Spatial Orientation and Technical Comprehension. A lower performance of females was also revealed with regard to Mathematical Reasoning. Advantages of the female group with respect to other aptitudes (English and Perceptual Speed) were found to be relatively small. Sex differences in personality were observed for aspects of emotionality, activity and interpersonal behavior. Females scored higher in scales of Emotional Instability, Empathy, and Achievement Motivation, but lower in scales of Vitality and Dominance.

INTRODUCTION

In its Hamburg Testing Center the DLR Department of Aviation and Space Psychology is running personnel selection programs - mainly for highly qualified operator careers in civil aviation. The two major fields of this work are pilot and controller selection. Traditionally, both areas are a male domain, but females were increasingly admitted for these occupations during the last decade. Today we find an unrestricted access of female applicants to the selection programs. Nevertheless this does not automatically result in a balanced distribution of both genders. Dependent on the target occupation one finds considerable differences in the composition of the population of applicants. While the population of applicants for Air Traffic Control (ATC) shows a reasonable percentage of 30-40% females, in the groups of airline pilot applicants females still form a clear minority of less than 10%. The reported percentages are representative for the recent years (GOETERS et al., 1988,1989).

Such distorted gender distributions indicate differential self-selection effects which can considerably influence the psychological composition of both gender groups. Consequently a comparison of both sexes might reveal more information about such preselection effects than about real sex differences. So one has to be very careful with the interpretation and generalization of observable psychological differences between both sexes. If one is interested in "true" sex differences, one should concentrate on those groups in which the differential self-selection effect is limited or can be ignored.

When females were first admitted to work as pilots or controllers there was a lot of speculation about their ability (or often presumed non-ability) to fulfill the requirements of these occupations. In this discussion objective information was often missing. This paper is written with the intention of presenting some objective results about sex differences based on experience in psychological selection. The study was stimulated by the fact that in the selection programs of aviation personnel females fail significantly more often than males. Is this the result of real personal deficiencies? Or are other explanations possible: e.g. a "chauvinistic" reaction of a dominating male environment? This paper tries to find answers to these questions.

In order to avoid or at least diminish the mentioned self-selection effects prior to the application this study uses only data which is collected from ATC applicants, who show a better, although not perfect balance of both sexes than pilot applicants. Another reason for chosing ATC applicants is that at the time of this study representative data was available only from ATC selection. Analyses of gender differences of pilot applicants will follow, when the data base has become sufficiently large.

METHOD

Before being transfered to the medical examination ATC applicants to the German Federal Administration of Air Navigation Services (Bundesanstalt fuer Flugsicherung BFS) have to pass a psychological evaluation with two testing phases including four selection steps:

First testing phase (Duration: 1 day, different in time and location from second phase):
- First step : Selection decision based on paper-pencil tests

Main testing phase (Duration: 3 days for those passing each selection step):
- Second step: Selection decision based on additional paper-pencil tests
- Third step : Selection decision based on apparatus tests
- Fourth step: Selection decision based on an interview

In this study only test results are analysed which were received before the first step of selection. These test scores are not influenced by the selection decision itself, while those recorded later are. In the first testing phase, which preceeds the first selection decision, aptitude tests as well as a personality questionnaire are administered. A list of tests is given in Table 1.

Table 1. Tests and associated aptitudes/traits used in the first testing phase of psychological selection of ATC applicants

Test	Sign	Aptitude / Trait
A. Performance		
Englisch (schriftlich)	ENS	Knowledge in English
Technisches Verstaendnis	TVT	Technical Comprehension
Rechenaufgaben	IRA	Mathematical Reasoning
Ungerade Zahlen	UZA	Auditive Attention
Bourdon	BOU	Perceptual Speed
Konzentrationsbelastungstest	KBT	Mental Concentration
Wegfiguren-Test	WFG	Spatial Orientation
B. Personality		
Temperament-Struktur-Skalen mit den Einzelskalen:	TSS	Personality Structure including:
Leistungsstreben	LEI	Achievement Motivation
Aengstlichkeit	AEN	Emotional Instability
Rigiditaet	RIG	Rigidity
Extraversion	EXT	Extraversion
Feindseligkeit	FEI	Aggressiveness
Vitalitaet	VIT	Vitality
Dominanz	DOM	Dominance
Persoenliche Waerme	WAE	Empathy
Verwoehntheit	VER	Spoiltness
Mobilitaet	MOB	Mobility

SUBJECTS

402 applicants for ATC training participated in the study. They were tested in September 1986. According to the basic entry requirements of the German ATC all subjects had at least a school education up to the Fachhochschulreife (limited university entrance level), but the majority had the Abitur (full university entrance level). The sex and age distribution of the total group of applicants is presented in Table 2.

Table 2. Sex and age distribution of the group of applicants for ATC training (First Testing Phase)

	Sample Size		Age	
	N	%	M	s
Total Group	402	100	21.1	2.0
Male Sample	285	70.9	22.6	2.3
Female Sample	117	29.1	20.1	1.8

The group of subjects taken for this study is not ideally balanced with respect to sex. Nevertheless, nearly 30% female applicants seem to be a reasonable percentage which is not indicating such an extreme selfselection influence as it can be detected for pilot selection (see INTRODUCTION). The age difference between males and females of approximately one year is mainly generated by the fact that most of the males have to complete the military service before they can apply, while females do not have such obligations after finishing school.

RESULTS

Gender effects on test results are investigated for all diagnostic methods administered in the first phase of testing (see METHOD). Means M and standard deviations s of the test results are separately computed for each sex. Thereafter means are checked for significance of differences.

Testing the significance of differences of means is the first step to identify the influence of gender, but it describes only in a limited way the magnitude of the effects. Therefore significance tests have to be supplemented by information, how much the distributions of test scores diverge between the compared groups. This information is given by a statistic which expresses the difference of means in terms of the average standard deviation of both sex groups. This statistic is calculated as DIFF(M)/S, where DIFF(M) is the difference of means and S is the averaged standard deviation.

GENDER DIFFERENCES IN APTITUDE TESTS

Table 3 shows means and standard deviations for the administered aptitude tests. These statistics are supplemented by information about the differences of means (last two columns of the table). The differences of means are tested for significance. The absence of significant gender differences can be detected in only a few tests. These are the test of Auditive Attention UZA and the test of Mental Concentration KBT. The other tests show significant differences. Females score significantly higher in the test of English Knowledge ENS and in the test of Perceptual Speed BOU. Males show up with significantly better results in the tests of Technical Comprehension TVT, Mathematical Reasoning IRA, and Spatial Orientation WFG.

The magnitude of the significant differences of means as indicated by DIFF(M)/S is highest for the three tests in which the males score better. Especially in the tests of Technical Comprehension and of Spatial Orientation the means of both sex groups differ more than one standard deviation. This is much more than the advantage which the female applicants hold in the tests of English Knowledge and of Perceptual Speed. Here the means differ only about a quarter of a standard deviation indicating that there is still a large overlap of both score distributions.

Table 3. Means M and standard deviations s of raw scores in aptitude tests, separately determined for male and female ATC applicants

		Male (N=285)		Female (N=117)			
Aptitude	Test	M	s	M	s	DIFF(M)	DIFF(M)/S
Knowledge in English	ENS	56.8	12.6	60.2	11.2	-3.4**	-0.28
Technical Comprehension	TVT	9.6	3.7	5.5	2.8	4.1**	1.26
Mathematical Reasoning	IRA	11.6	3.8	8.9	3.2	2.7**	0.77
Auditive Attention	UZA	43.4	4.6	43.6	4.2	-0.2ns	-0.00
Perceptual Speed	BOU	210.4	37.8	218.2	31.7	-7.8*	-0.22
Mental Concentration	KBT	86.4	23.2	85.4	21.8	1.0ns	0.04
Spatial Orientation	WFG	25.4	11.9	15.5	7.7	9.9**	1.01

Significance of the difference between means: * $p<0.05$, ** $p<0.01$, ns = not significant

The distribution of raw scores of the tests of Technical Comprehension TVT and of Spatial Orientation WFG are presented in Figures 1 and 2, respectively, in order to get a precise idea about the divergence of sexes in those two tests which show the largest gender effects. Although an overlap of the score distributions of both sexes exists, it can be clearly seen in these figures that a considerable part of the male group exceeds the total female distribution, while only a small part of the female group is just able to surpass the mean of the male distribution.

GENDER DIFFERENCES IN PERSONALITY SCALES

Table 4 shows means and standard deviations for the scales of the personality questionnaire TSS. The statistics are presented in the manner which is already known from Table 3. Significant differences of means can be identified in scales of emotionality, activity, and interpersonal relations. In both scales of emotionality, Emotional Instability and Empathy, female applicants score significantly higher. In two of the activity scales the effects are controversial. Females score significantly higher in Achievement Motivation, but lower in Vitality. In one scale of interpersonal relation, namely Dominance male applicants score significantly higher than the female group. In all other scales no significant differences could be detected.

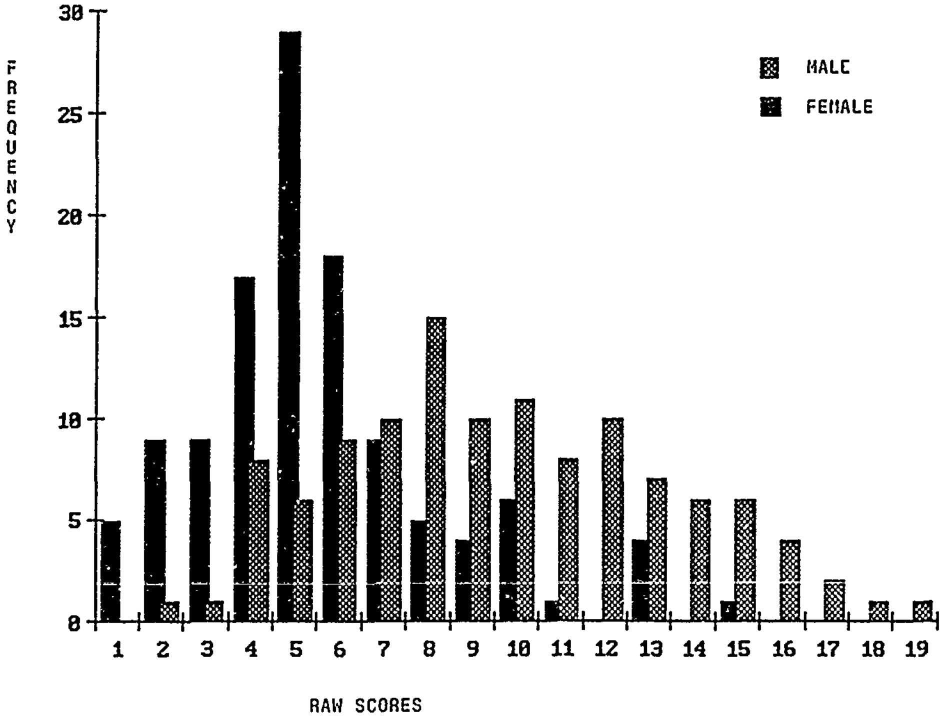

Figure 1. Distribution of raw scores of the test of Technical Comprehension TVT, separately documented for male and female ATC applicants

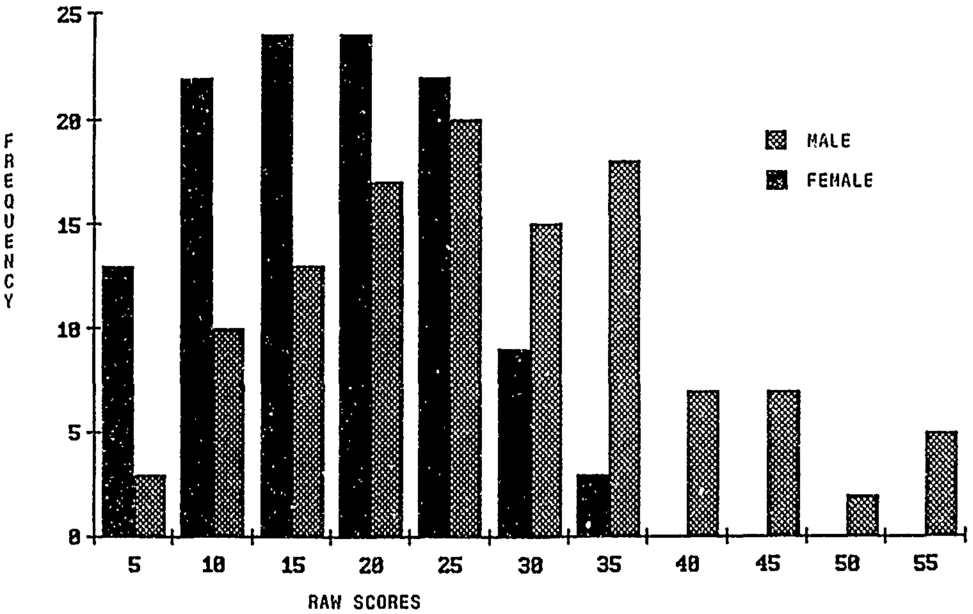

Figure 2. Distribution of raw scores of the test of Spatial Orientation WFG, separately documented for male and female ATC applicants

Table 4. Means M and standard deviations s of raw scores in personality scales, separately determined for male and female ATC applicants

		Male (N=285)		Female (N=117)			
Personality Trait	TSS-Scale	M	s	M	s	DIFF(M)	DIFF(M)/S
Achievement Motivation	LEI	10.3	4.2	11.2	3.9	-0.9*	-0.22
Emotional Instability	AEN	8.8	5.0	10.4	4.9	-1.6**	-0.32
Rigidity	RIG	13.6	5.0	12.7	5.3	0.9	0.17
Extraversion	EXT	14.6	5.0	14.9	4.8	-0.3	-0.06
Aggressiveness	FEI	9.7	4.4	9.1	4.4	0.6	0.13
Vitality	VIT	12.8	5.3	11.4	5.2	1.4*	0.26
Dominance	DOM	11.0	5.2	9.5	4.8	1.5**	0.30
Empathy	WAE	12.5	5.1	15.2	4.5	-2.7**	-0.56
Spoiltness	VER	12.8	4.9	13.8	5.2	-1.0	-0.19
Mobility	MOB	10.9	5.1	11.0	5.2	-0.1	-0.01

Significance of the difference between means: * $p<0.05$, ** $p<0.01$, ns = not significant

GENDER DIFFERENCES IN THE SELECTION PROCESS OF ATC PERSONNEL

It was mentioned above that the psychological selection of ATC applicants is consisting of four selection steps which always precede the medical check (see METHOD). After being accepted by the medical check the applicants receive their contract for ATC training. Table 5 presents information concerning the percentages of male and female applicants passing to the various levels of the selection process. Table 5 also reports selection rates associated with the various phases of ATC recruitment.

Table 5. Number of applicants participating at the various steps of the selection process for ATC training (expressed in percentages related to the total group of applicants starting in the first testing phase) and selection rates (= probability of being accepted) associated with the selection steps

	Participation		Selection rate	
	Male	Female	Male	Female
Psychological Evaluation				
First testing phase: Paper-Pencil Tests	100%	100%	45%	31%
Main testing phase : Paper-Pencil Tests	45%	31%	65%	47%
Main testing phase : Apparatus Tests	29%	15%	74%	64%
Main testing phase : Interview	22%	9%	79%	83%
Medical Examination	17%	8%	84%	88%
Accepted for ATC training	14%	7%	--	--

As can be seem from Table 5, expressed in percent twice as many males than females reach the application goal and are accepted for ATC training. The major difference between both genders arises already after the first psychological testing phase. Here 45% males, but only 31% females were accepted based on the results of the first testing phase (see also METHOD) and therefore were allowed to pass to the next phase. The magnitude of the gender difference persists until the interview. Up to that phase all selection decisions are based nearly exclusively on objective test results by using replicable decision rules (KRUSE, 1989). There is - if ever - only limited space for a chauvinistic rejection of females. The explanation for the differential selection effect of both sexes must be expected to be a result of differences in the test results. Chauvinistic selection decisions even do not appear as a considerable factor when the psychological evaluation becomes more subjective in the interview phase. Just the opposite is true: During the interview it is more likely to pass as a female than as a male applicant as can be seen from the selection rates which at this step favor the female group.

In the first testing phase the results of the personality scales are used for selection only in the case of extreme negative data variations. Predominantly the results of the personality questionnaire are taken to generate hypotheses which should be checked during the interview. Therefore, the differential selection effect arising already after the first testing is mainly based on the aptitude tests applied in that early phase (see Table 1). The results which were presented in Table 3 clearly indicate that the deficiencies of the female group in the tests of Technical Comprehension, of Spatial Orientation, and to a lesser degree also in the test of Mathematical Reasoning are not counterbalanced by similar female advantages in other areas. Especially Spatial Orientation, which is also a source of variance for the test of Technical Comprehension, is an important criterium for tne selection of air traffic controllers.

In the test of Spatial Orientation WFG the critical cut-off point for acceptance or rejection is a raw score of 16 what corresponds to the lower limit of a STANINE score of 5 (= medium range) as received from the total population of applicants (male and female). For those readers not familiar with the STANINE scale it should be mentioned that test raw scores are usually transformed into standard scores. By this operation a scale of measurement is received which is independent of the unstandardized raw score distributions of test results. STANINE scores are standard scores varying between 1 (= lowest score) and 9 (= highest score) with a mean of 5 and a standard deviation of 1.96. As can be seen from Figure 2 a raw score of 16 in the WFG classifies half of the female group as critical, but only about 20% of the male group. Similar differences in the classification of both sexes are also to derived from the raw score distribution of the test of Technical Comprehension TVT (see Figure 1).

DISCUSSION

The results which were revealed by this study concerning sex differences in aptitudes and personality traits fit well into textbook knowledge of Differential Psychology (ANASTASI, 1965, p.470-492). So, this study does not contribute new information to basic science. The value of this paper can be seen in the fact that it shows the existence and influence of psychological differences between genders in a specified environment.

The identification of differences in Technical Comprehension, Spatial Orientation and and to a minor degree in Mathematical Reasoning as the main source for differential selection effects of both sexes in the recruitment of ATC personnel is neither a sample specific nor a typical German phenomenon. An investigation of MANZEY et al.(1990) revealed nearly identical effects in a sample of Spanish applicants for pilot training. Technical Comprehension, Spatial Orientation, and Mathematical Reasoning can be seen as basic abilities which help to master and use technology. Sex differences in these abilities are documented since many decades (ANASTASI, 1965, p.475). In the past these differences were often interpreted as a result of the traditional education. It was presumed that the mastery of technology is much more reinforced in boys than in girls. The typical behavior pattern which helped to explain this presumption was seen in the fact that parents prefered presents of technical toys (e.g. model cars) for boys and made presents of more care demanding toys (e.g. dolls) to girls. During the last two to three decades the educational goals in Europe and in other developed or developing parts of the world have changed to reasonable degree, as did many other values of the societies. Today a lot of parents (and even teachers at school) consciously try to practice an unbiased education. It can be observed that the gender differences in Spatial Orientation are continuously decreasing during the last decade (1978-1988) - probably as a result of significant changes in education (STUMPF & KLIEME, 1989).

Nevertheless, one has to acknowledge that sex differences in certain basic aptitudes still exist to such an extent that the occupational perspectives of young people are directly depended of their gender when they apply for a career as operators in aviation. Because work demands in operational tasks as those of pilots or controllers are essentially the same for both sexes, also the same selection criteria must be fulfilled. Such a selection strategy has been proved to be effective as it is shown by the results of a follow-up study for German ATC trainees. This study could not detect any differences in training success between both sexes. A report about this study is under preparation by DLR.

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Psychological and sociological aspects of the entrance of female aircrew to the Norwegian Airforce.

by

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Female and male individuals are expectet to react differently in most situations. The behavior of a person is almost always judged in conjunction with a set of stereotyped expectancies. In the footsteps of the Feminist movement stereotypes of men and women have been the target for many studies. The results from these studies indicate conceptions of what is typical feminine and what is typical masculine traits. Boverman & al (1972) and Rosenkrantz & al (1968) have in their studies isolated two distinct clusters of traits which are seen as distinguishing women from men. The first cluster contains traits considered to reflect competence, while the other cluster contains traits related to warmth and expressiveness. Men are usually thought of as competent and energetic.

The competence and energy cluster contain traits high on active, ambitious, competitive, dominant, independent and self confident, while the opposite of each of these traits is associated with women. There has been little change in these general set of stereotypes since these studies were performed, most traditional ideas are still held. Stereotypes constitute a set of expectancies or attitudes for the individual performer. What is interesting to note is that these stereotypes also color our everyday attributions as males and females, and may explain why we still have few female applicants for undergraduate pilot training. The attribution process when it comes to evaluating female applicants and female aircrew, has to be considered in relation to sex. Many people are still surprised why the number of female applicants are scarce. Some regards this as a proof that piloting is not a task for women, while others question why the number is still low. In Norway the first female candidate for military flying training was admitted in 1982.

In 1985 the Norwegian Govenment allowed through a general permission all positions to be opened for women in the Armed Forces. By this permission females were also allowed to become combat fighter pilots in the Royal Norwegian Air Force (RNoAF).

The selection program for pilot applicants, male and female is illustrated in figure 1.

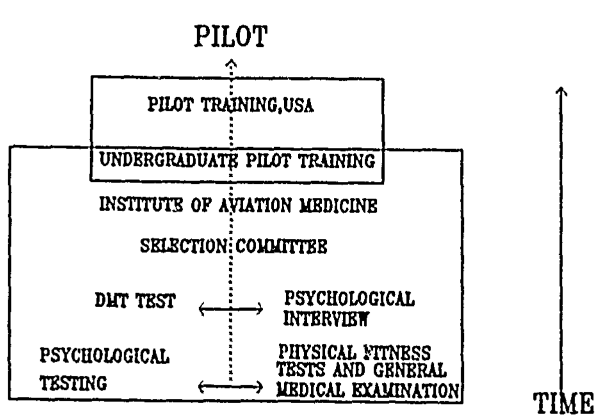

Figure 1

TESTS	AIM OF TESTING
RAVEN PROGRESSIVE MATRICES NUMBER SERIES	GENERAL ABILITY LEVEL
SURFACE DEVELOPMENT TEST FIGURE PATTERN TEST FIGURE FORM TEST TECHNICAL COMPREHENSION	TECHNICAL COMPREHENSION AND SPATIAL ORIENTATION
SORTING TEST REVERSAL TEST NUMBER IDENTIFICATION INSTRUMENT COM-PREHENSION	SIMULTANEOUS CAPACITY
SPATIAL ORIENTATION MIRROR TRACING TEST TIME ESTIMATION	TRANSFER OF PRINCIPLES CONFUSION OF DIRECTION
	DEFENCE MECHANISM TEST

Figure 2

The content and aim of the psychological testing is illustrated in figure 2. These requirements are the same for both sexes. Concequently the female applicant for graded pilot training in RNoAF compete for admittance, education and future positions on the same terms as their male counterpart.

Although limited in number, since only 7 female aircrew (2 operative pilots, 2 system operators and 1 navigator and two pilots in training) have met the entrance requirements, female aircrew may still represent a foreign body in the presumably well oiled male machinery constituting an air crew. Since success in aircrew cooperation may be reflected in flight safety we felt it important to investigate to what extent females are accepted as crew members in the RNoAF, both on the wing (squadron) and in flight. Furthermore we have looked at the number of female applicants through the selection process and on their psychological test scores as compared to those of the males'.

METHODS

Firstly the total number of applicants for pilot screening and officer school in the Royal Norwegian Air Force (RNoAF) from 1982 to 1989 were studied in order to reveal the fate of the female applicants during these years and establish if the females accepted represent a fairly constant percentage of the total number of applicants, similar to the male population where approximately 10% of the total number of applicants are accepted.

Secondly we have compared the results from the psychological tests for 17 female applicants admitted to pilot screening and officer school, with those of 173 accepted male applicants. We did not look at the results from each separate aptitude test, but at the results from the groups of tests. (i.e. General Ability Level tests, Technical Comprehension and Spatial Orientation tests, Simultanous Capacity tests and Transfer of Principles - Confusion of direction tests). These test groups are based on results from factor analyses of the whole test battery. The raw scores from each test are transferred to a scale divided into nine groups (stanine scale) to make the interpretation of the results simpler. As a rule the applicant has to obtain scores in group 5 or higher in order to be accepted.

Thirdly we have performed a survey in the RNoAF, in order to map the attitudes of squadron commanders and flight commanders (34 males) about their professional experience with the present female air crew in the RNoAF (5). In addition the females (5) answered questions regarding how they experience their situation seen from a female point of view. This survey consists of 36 questions covering subjects like recruiting, education, working conditions, cockpit cooperation, view of pregnancy and general comments.

RESULTS

During the period covering 1982 to 1988 RNoAF received a total of 4694 written applications for acceptance to graded pilot training. Out of this number 2488 (200 females) of the applicants met the formal requirements and were summoned for the main intake procedures. From this group 450 applicants passed the physical tests, the psychological tests and the medical examinations, 22 of these were females.

It seems a general trend that a larger percentage of females is eliminated during the selection process than males. This trend was unambiguous in the years 1982, 83, 84 and 1986. 1987 was the first year where the female percentage was kept stable throughout the whole selection process. The numbers from 1988 is not yet available since the candidates are not yet checked out on flying qualifications. Consequently,

19.6% of the male applicants and 12.5% of the females have passed the selection process so far. During the years 1982-1986 the females performed even poorer, while this negative trend seems to have stopped in 1987, when the percentage of accepted applicants was similar for the two sexes.

Figure 3 illustrates the percentage distribution of female applicants through the different phases of the selection process. 8.59% of the female applicants are accepted in the regional intakes, 7.64% are admitted for the main screening process. 4.65% of the original number are accepted at this level while only 3.92% of the females are allowed to start flying training. In the end 1.82% of the females are accepted for undergraduate graduate pilot education in the U.S.A. (Figure 3).

Selection of pilots – percentage of women
in the different tests

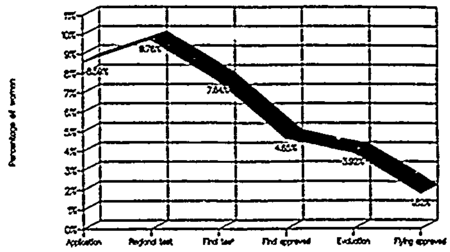

Figure 3

Table 1

TEST RESULTS FROM PILOT SELECTION
stanine scores

	FEMALES (n=19)		MALES (n=173)	
General ability level	$\bar{x}$ 6.12	SD 1.20	$\bar{x}$ 6.17	SD 1.27
Technical comprehension and spatial orientation	$\bar{x}$ 5.63	SD 1.12	$\bar{x}$ 6.39	SD 1.22
Simultaneous capacity	$\bar{x}$ 6.44	SD .86	$\bar{x}$ 6.41	SD .94
Transfer of principles	$\bar{x}$ 6.35	SD 1.12	$\bar{x}$ 6.83	SD 1.30

Table 1 reveals the average stanine scores from 19 female applicants and the average scores from 173 male applicants, combining the subtests within each main test group. There are no statistical differenses between the two sexes on any of these tests.

Looking at the raw scores from the general ability level tests the females are doing poorer than the males on typical technical tasks like instrument comprehension, spatial orientation and mechanical comprehension. They were, however, slightly superior in tasks involving simultanous capacity. In the other tests there was no difference between male and female scores.

The answers to the different questions in the survey differ little between the two groups. The main reason for choosing to become a pilot was "interest" for both sexes.

The question "Do you feel that the present selection process favours men?". Only three out of 34 men answered "yes" and one out of 5 females answered "yes", while the rest of the participants experienced the selection as fair.

One of the statements in the survey says that 5 out of 10 men are accepted for flight training after the selection process while only 1 out of 10 females. How do you explain this difference? Seventeen of the men answered: "Men are better suited for this kind of work," while 6 judged it to lack of motivation on the girl's part. Four of the females ascribed this to lack of confidence and unrealistic expectations.

None of the female pilots reported any negative experience with the instructors during training.

To the question "Are you satisfied with your job experience and possibilities so far?" All but one female and all but one male gave affirmative responses.

"Are there any tasks that female pilots are less fit for than male pilots?" To this question five of the males answered that females were not suited for fighter planes because of their anatomy and psychology, aside from that they may do all kinds of work.

The females in the survey did all agree that aside from the pregnancy period, females are fit for the same tasks as males, provided they have passed the screening process.

One of the questions in the survey covered the argument about menstrual distress and pains as a factor against female pilots. To this question all of the females answered that women with so called typical feminine, monthly problems will never apply for graded pilot training. The men in the survey apparently believe these problems to be the same for all women, as long as female pilots are allowed one has to accept and get used to these problems!

"How are female air crew performing their jobs at the squadron/unit?" Five of the men in the survey answered that they had no experience with female aircrew, two thought the females were not according to standard technically set, while the rest of the males rated them as equal to men.

One of the 35 men participating in the survey was negative to working with female pilots in cockpit. The 34 others reported positive reactions. Five of the males even consider female air crew as having a positive effect on the working conditions in cockpit! All the females reported positive experiences in cockpit cooperation.

Female air crew and pregnancy is a topic were one would expect the two sexes to express large discrepancies. However, both groups felt that this is not a major problem. Both males and females seem to accept that as long as the RNoAF has accepted female air crew this is a small problem and that this has to be solved in conjunction with the Institute of Aviation Medicine.

The females did not agree in the present policy of the RNoAF, stating that pregnant air crew are grounded from the day pregnancy is confirmed and to the end of the breast feeding period.

"What is the ideal pilot like?" One of the females had no explicit view regarding this question, while the rest of the females gave the same answer as all but one of the men: Good craftsman, openmindness and able to cooperate. The one male dissident answered that the ideal pilot was just like himself!

DISCUSSION

As can be seen from the results in figures and table there are no major differences concerning general abilities between female and male aircrew applicants. The number of females in the survey is very small and does not enable us to make any conclusive statements, but they demonstrate that the differences between the two sexes are within one standard deviation. One may find larger intragroup differences than intergroup differences between the sexes. The differences that are revealed in the technical tests might reflect different levels of experience through childhood and upbringing for the two sexes, and not be explained by different levels of ability. The two groups seem to belong to the same population with respect to the tested abilities.

Piloting and aviation have been associated with specific sexlinkage of a task. It takes a very special woman to challenge the men on their established premises. She not only has to convince simply the selection committee, but the instructors, their fellow colleages and the whole system. Miller and Ross (1975) interpreted strategies of self-attribution as a logical information-processing rather than an ego-defensive mechanism. Typical masculine and feminine tasks are perceived to have different degrees of difficulty, thus attribution for success and failure on these tasks should have different kind of information for both actors (the flying students) and the observers (the instructors). An attribution of a woman's performance to luck instead of ability may lead an observer to hold less promise for the future performance of that woman.

For instance a successful female pilot student is more readily evaluated as having been lucky with her performance, not as being particular able for the task.

With these different evaluation criteria between the sexes in mind one may understand some of the psychological test results and reported experiences with female aircrew. Our attributional pattern is not biologically inherited, but psychologically inherited through different sex expectancies when it comes to achievement.

As revealed in the present paper both the test results and the every day experience with female air crew are in fact optimistic. The males are not as negative toward female "intruders" to the system as some expected them to be, and the females have not stopped the wheels from turning smoothly. If our aim is to make room for more female aircrew or to change the attitude that this might represent a problem, the question that still remains unanswered is how to change these "inborn" expectancies.
One successful female pilot is not sufficient to revise such expectancies not even for the sex in question. Women are known to preserve their self-evaluation patterns in a vicious cycle due to lack of self-confidence. A consistent set of success or failure experiences of some duration of time should allow a reformulation of expectancies to reflect past experience more accurately.

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EVALUATION OF FEMALE AND MALE AIRCREW APPLICANTS USING A COGNITIVE AND PSYCHOMOTOR TEST

by

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INTRODUCTION

Since the begining, Aviation has been an activity almost exclusively related to men.Nevertheless, over the last few years there has been an increasing number of women involved in the aeronautical world, a field which has not exclusivly been available for men, not even in the Armed Forces.

In spite of this increasing trend, the number of women aircrew is still very few in comparison to the number of men. Consequently, almost all the research carried out on "human factors" within the Aviation enrironment has been done in relation to the male sex.

Human performance within a task, whatever it is, results on the "interaction of various variables", such as the task, the environment, the individual, and so on, among which sex is another one to be considered. For the time being, we have not enough information to determine whether or not the sex variable is relevant within piloting tasks.

We do not know whether women -as a population- have better plying aptitudes than men, or whether the difference in sex makes any difference in handling and solving aeronautical stress situations.

The decision to recruit women into the Spanish Air Force and, particularly, to helicopter aircrews, transport and fighter aircraft, raises certain questions about their physical and psychological performance at the aircraft controls.

Those questions will only have a satisfactory answer in few years after their total integration.

In the meantime, there are certain relevant aspects to be investigated in order to get a first approach to future projects.

MATERIAL AND METHODS

The whole task of piloting an aircraft consists of a set of simple tasks which involve sensory, cognitive and psychomotor processes, some of which are very complex, each of them imply in turn different modalities:

- -Attention (divided and concentrated)
- -Perception (visual and auditory)
- -Information processing (discrimination, integration, categorization)
- -Decision-making
- -Psychomotor response (hand, foot, voice, etc.)

This is a very simple description on behaviours that "occur" when the pilot handles aircraft controls while performing an air operation. In each flight stage a repetition of this set of processes takes place until the operation is completed, even though the pilot is not aware of them.

These are sequential processes, each of them produces an effect on the following ones. If any of these steps are done incorrectly, the whole operation fails together with the final result. So, therefore the success of the flight will always depend upon the accuracy in performing all these procesesses in each sequence (attention, perception, decision and response) corresponding to each step of the flight.

We could say that a "good pilot" is the one who makes few errors in each sequential processes mentioned above or one who at the end of each sequence makes an appropriate response, thus demonstrating that the previous steps have been solved correctly.

We can also assume that these perceptual, cognitive and psychomotor abilities are both basic and previous to learn flying. They could be improved through training, but nobody who is evaluated in "ab initio" selection could become a good pilot if he or she has not a minimum amount of the above mentioned abilities.

Taking into consideration these premises, the Spanish Institute of Aviation Medicine (CIMA) has developed a system and the equipment for the assesment of performance of this sort of complex tasks, which will be used for the evaluation of candidates cognitive and psychomotor abilities in order to became a pilot. This system also permits the investigator to evaluate the learning capability of an individual in those tasks which require a sequential processing such as the one mentioned.

The equipment consist of the following parts:

- -Modules for the programming and emission of visual and auditory stimuli.
- -Desks with devices for transmission of stimuli (visor and headsets) and responses (two buttons and two pedals).
- -Modules for the recording, counting, and timing of responses produced by the subject.

The procedure requires that the subject has to give a response to the programmed stimuli (right or left hand, right of left food) according to a previous criterion established after the significant physical features of each stimulus, which have previously been divided into four categories. The subject briefed about these categories and about the elements corresponding to each category; a script containing the four categories and their respective responses -but not the elements- is left at his sight.

The subject must pay attention, perceive, process, decide, and give a response to each of the stimuli that appear, and he or she is given a score according to the number of correct answers in each st of previously determined stimuli. Then, after an interval of 45 seconds, the same series of stimuli is repeated, this time with no verbal instructions.

For this test two identical 45 stimuli series were established (trial 1 and trial 2) free of aeronautical significance in order to avoid interferences of any possible previous experience.

Two types of scores were obtained from this double evaluation:

1- Performance: number of correct answers in each series (R: R1, R2)
2- Average time of perception, processing and response (T: T1, T2)

This test was administered to a sample of 135 subjects, 115 males and 20 females; they were applicants for a commercial pilot licence. The age ranged from 17 to 25 years, and nobody had any previous piloting experience.

The goal of the experiment was focused on testing whether there were significant differences between men and women in the cognitive-psychomotor task assigned. In other words if the factor sex influences on the performance (R) and on the average time of response (T), considering as a null hypothesis that there are no significant statistical differences between the group of males and the group of females.

The statistical analysis of the results obtained from each subject in both trials was oriented to verify the null hypothesis, establishing a confidence level of 0.005. Consequently the analysis of variance was done over the scores obtained by the overall group in trials 1 and 2 regarding the variables sex and performance (R1 and R2); the analysis of variance was also conducted on the repeated measures of R and T in order to assed if the learning produced by repetition of the trials was significantly higher in one group compared to the other.

RESULTS

The average of performance in the total sample of the pilot applicants was found to be higher in the female group, in both trials, than in the male group. The female group was also found to improve its scores to a higher extent than the group of men, meaning that women learned more than men in this task.

Nevertheless, the probability associated with the F of Fisher value results in all cases higher than the confidence level established of o.05, and its statistical significance does not permit to discard the null hypothesis. This infers that the variance of the performance results cannot be attributed to factor sex.

In the same way, the analysis of variance referred to the variable time (T1 and T2) was done. The results in this case were slightly better in the group of males in both trials. But the difference of the means were higher in the first trial than in the second one. This infers that women respond slower to the test stimuli, but improve their results in the second series in comprison to the first, with respect to men.

Similarly to what happened with the variable performance, the statistical results of the relationship between the variable time and the sex do not permit us to rule out the null hypothesis. The probabilities associated with the respective F are bigger than those which would allow us to state that the differences between means are significant at a confidence level of 0.05. Therefore, we have to accept that both groups, males and females, have similar results with respect to the variable T, and that the differences found cannot be attibuted to the factor sex.

There is another aspect to be considered related to learning when an individual repeats the same task in two consecutive trials. The probability associated with F in the analysis of variance of repeated measures in variables R and T is of 0.001, remarkably lower than the level of significance 0.05 pre-established in this experiment. This infers that there is a rate of learning in the group that could be used as a reference for discrimination while evaluating and rating an individual's learning degree once it is considered as typical or significantly different than the population average.

DISCUSSION

The statistical analysis shows that the results obtained in the pilot applicants in the cognitive-psychomotor test proposed were not significantly different in men compared to women.

Dependent variable chosen for this experiment, performance and average time of perception, processing and response, are not affected by the sex of the subjects.

With respect to the rate of learning of a subject in the test, available data suggests that there is a "learning factor" related to the complex cognitive and psychomotor tasks that could be useful as a prediction criterion over the capacity of an individual to learn rapidly and efficiently the most important piloting tasks. This learning factor is as the variables performance and time of perception, processing and response, independent of factor sex.

All the above mentioned factors do not necessarily mean that there are no other possible physiological or psychological variables related to the factor sex and the overall performance of the pilot. There could be several personality factors and others that, for the time being, offer an attractive field for investigation both in Medicine and Aeronautical Psychology.

The validity and reliability of the system, procedures and equipment used for this experiment need further evaluation, so that they can be used as a tool for initial pilot selection. This can only be achieved by means of a close follow-up of the male and female applicants during their flight training perior, and afterwards as professional pilots. This will give us a better knowledge about the psychological variables that could be related to factor sex and give the test validity.

FEMALE AIRCREW - THE CANADIAN FORCES EXPERIENCE

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SUMMARY

Data collected since females first started aircrew training in Canada in 1979 is reviewed. Females are less successful than males in selective competition for training, but once into the training scheme there is no significant sex difference in achieving WINGS standard. Although numbers are still relatively small, female aircrew are now participating equally with their male peers in all aspects of military flying including tactical fighter operations.

HISTORICAL PERSPECTIVE

Once upon a time, only men could become operational pilots in the Canadian Forces (CF). In fact, only a limited number of military occupations were open to women, and this policy was based more on tradition and social practice than any scientific basis as to whether either sex could best do the job. Evolving demographic patterns and the changing roles for women ongoing within most societies have caused military planners to consider an expanded occupational potential for women in the military. In Canada, such considerations were intensified during the 1970s largely as a result of Federal Government policies directed to providing equality for men and women in the workplace culminating in the promulgation of the Canadian Human Rights Act in 1977. The Act prohibits sexual discrimination in the employment of an individual unless the employer can establish that the discriminatory practice is based on a bona fide occupational requirement.

The CF response was to establish a trial the purpose of which was to determine the effect of employing Servicewomen in Non-traditional Environments and Roles (SWINTER), but short of full combat duties. The purpose of the Aircrew part of the Trial was to assess the impact on operational effectiveness of employing servicewomen in five previously all-male non-combat squadrons in transport, search and rescue and in training. The trial concluded in October 1985. Recruiting was temporarily suspended between 1984-86 while trial results were being analysed, but active recruiting of female aircrew applicants recommenced late in 1986 and has continued to the present.

The Surgeon General was required to determine what the medical selection standards for female aircrew applicants should be prior to commencement of the trial. Participants for the trial were to be selected forthwith, so a rather hastily called meeting attempted to address the question. A major concern was female upper body strength to do the job, particularly in an emergency situation with loss of operative aircraft systems. A decision was made that the minimum acceptable body weight for females would be some 12% greater than the smallest acceptable male which would equate to at least equal lean body mass with some correlation to similar strength. It was well understood that any standard would likely be challenged under the Human Rights Legislation and such a minimum weight requirement had some scientific validity and was reasonable considering the time constraint. All other standards would be the same as for males.

Candidates for the SWINTER trial were to be selected from the current servicewoman population i.e. from women already serving in other military occupations. The Aircrew Trial specified that 28 women (i.e. 20 pilots, 4 navigators and 4 flight engineers) were to be trained and employed in operational postings; that number was expected to represent some 10% of serving aircrew in selected squadrons and allow a meaningful evaluation. It became apparent that the required numbers for pilot/navigator would not be available from the servicewoman pool and the competition was soon opened to civilian applicants as well. It was also found that the supplementary minimum weight standard for females was impractical to apply and the medical selection standards for females became the same as for males.

CURRENT CF AIRCREW SELECTION PROCEDURES

The selection of aircrew (pilot and navigator) applicants begins at the local recruiting centre which includes a medical examination. Applicants who satisfy the initial criteria proceed to the second stage of selection at the CF Aircrew Selection Centre (CFASC) and the Central Medical Board (CMB) in Toronto. Assessment here includes a cognitive test battery, a psychomotor test, and an aircrew medical. Results are forwarded to National Defence Headquarters for the third phase where the Directorate of Recruiting and Selection (DRS) considers all information, makes their selection decisions, and authorizes enrolment.

The testing done at CFASC is comprised of the tests listed in table 1. Previous and current research has demonstrated that indices based on the test results are predictive of success in aircrew training.[8] The Visual General Aviation Tester (VGAT) measures the applicant's ability to coordinate body movement to manoeuvre the trainer in specific patterns using aircraft-type controls singly and in combination.

Table 1. ASC Tests Used to Form Predictive Indices

Test Title

*Numerical Ability
Verbal Aptitude
*Arithmetic Aptitude
*Technical Reading Comprehension
*Mathematical Reasoning
*Instrument Reading
Table Reading
Serial Addition
*Visual General Aviation Tester

*Males score significantly higher in these tests.

The aircrew medical at CMB is designed to meet the exacting CF recruiting policy of universal assignability, that is, that successful applicants must be medically fit to fly all aircraft in the CF inventory. Table 2 lists the assessment procedures.

Table 2. CMB Medical Assessment

1. review of data collected at Stage 1, which includes:

   a. physical examination,
   b. ophthalmology,
   c. audiometry,
   d. chest x-ray,
   e. electrocardiogram,
   f. laboratory results - blood type, serology, hemoglobin, white cell count, fasting blood sugar and cholesterol, urinalysis with microscopic.

2. repeat of any test not done or outside normal limits,
3. anthropometry with measures of standing height, seated height, thigh length and leg length,
4. pulmonary function studies,
5. electroencephalography,
6. echocardiography (since 1985), and
7. review of health history questionnaire and physical examination by the flight surgeon.

METHODS

Data collected concerning sex differences in CFASC test results has been summarized. The medical records of female applicants have been reviewed for the period 1979-1988 to determine if there has been any sex difference in medical suitability for aircrew training. Training statistics were then evaluated, again to see if there has been any sex difference in training success rates. Finally, a search was completed to determine the current population of successful female aviators and where they are employed in the CF.

RESULTS AND DISCUSSION

Aircrew Selection - CFASC Testing

Candidates perform the tests listed in Table 1. These tests are numerically weighted depending on their predictive value insofar as probability of success in pilot or navigator training is concerned. Pilot and Navigator Aptitude Indexes are calculated based on the candidates' scores. The Aptitude Indexes range from 1 to 9; the higher the Index, the greater the probability of success in training. Applicants with Aptitude Indexes of 5 or less are not typically selected.

Table 3. Percentages of Male and Female Applicants at Each Pilot Aptitude Index 1979-1982.

	Pilot Aptitude Index									
	1	2	3	4	5	6	7	8	9	Mean
Females (N=167)	11	6	15	18	15	16	9	7	1	4.45
Males (N=2451)	3	6	9	14	20	17	17	10	5	5.4

Surveys were conducted of candidate performance at the CFASC during the SWINTER trial period; results are listed in Table 3.[4] It demonstrates that only 33% of females while 49% of males achieved indexes of 6 or better. More recent CFASC results at Table 4 demonstrate that females have not closed the gap in their success rate with their male counterparts, and there continues to be a significant difference between the two groups.

Table 4. Male and Female Applicants Achieving a Pilot Aptitude Index of 6 or better.

	Female		Male	
	N	Successful	N	Successful
1987	132	24 (18.2%)	886	327 (36.9%)
1988	136	32 (23.5%)	984	422 (42.9%)
1989	111	20 (18.0%)	1035	465 (44.9%)

It has been evident that females are superior only in verbal ability and clerical speed and acuracy; males are superior in mechanical reasoning, visual spatial ability and quantitative ability.[8] Generally speaking, twice as many male candidates as female can be expected to achieve a successful Pilot Aptitude Index. There has been no sex difference on the Navigator Aptitude Index.

Aircrew Selection - Medical Assessment

The medical files of 477 female aircrew applicants were reviewed for the period 1977-1988. 149 of the 477 applicants did not meet the medical standard for pilot selection, a medical rejection rate of 31.2%; the reasons for medical rejection are summarized in Table 5.

Table 5. Reasons for Medical Rejection of 149 out of 477 Female Candidates 1979-1988

Reason	Total Candidates (N =477)	Percentage of Rejected Candidates (N=149)
Anthropometry	61	40.9
Vision	55	36.9
Neurology	16	10.7
Cardiac	12	8.1
Orthopedic	3	2.0
Hearing	1	0.7
Respiratory	1	0.7
Total	149	100

A previous review of all candidate documents for the ten year period 1978-1987 demonstrated an overall medical rejection rate of only 20.3% with 7743 males and 346 females in the survey.[7] A comparison of the reasons for medical rejection in this predominantly male group at Column 1 of Table 6 demonstrates that the only significant difference with the female group is in anthropometry, and it is the major reason for medical rejection in females.

Table 6. Comparison of Reasons for Medical Rejection in Male and Female Candidates.

Reason	Percentage of Total Candidates (N=8089)	Percentage of Female Candidates (N=477)
Anthropometry	2.5	12.8
Vision	11.6	11.5
Neurology	1.5	3.4
Cardiac	2.2	2.5
Orthopedic	0.1	0.6
Hearing	0.3	0.2
Respiratory	0.9	0.2
Other	1.2	
Total	20.3 %	31.2 %

Table 7 shows the current CF anthropometric standards. These standards are based on a survey of serving aircrew, 314 pilots and 293 navigators, published in 1966.[5] The first and 99th percentiles were taken as minima and maxima respectively, and present research would indicate that they may be too lenient for some of our current aircraft. To date, we have been able to insist on these standards although there are two cases of civilian pilots, who were turned down, before our Human Rights Commission awaiting a ruling. Their particular leg lengths were 98.3 and 97.4 cm.

Table 7. CF Anthropometric Standards for Pilot

	Min (cm)	Max (cm)
Standing Height	157	194
Seated Height	86.4	100.3
Thigh Length	54.6	67.3
Leg Length	99.6*	123.2

*Note - The minimum leg length standard was changed in 1982 from 101.6 to 99.6cm.

There is a third candidate who did not meet the standard but did manage to enter the pilot training program through an administrative waiver. Her measurements were satisfactory except for leg length of 95.0 cm. She was removed from pilot training approximately eight trips short of achieving her wings. The unit flight surgeon, after reviewing her training file, considered it unlikely that anthropometry was a factor,but that the failure was more likely related to personality and an inability to consistently react well in high stress situations. Notwithstanding this opinion, it is generally accepted that our fixed-wing training aircraft, the CT 114 Tutor, has one of our more accomodating cockpits. It is also documented that she had to fly with the seat low to ensure adequate rudder control resulting in a very low seated height and she did experience significant problems in the formation phase of training.

Table 8 illustrates the overall CFASC/CMB experience from 1979-1989. To have been SUCCESSFUL to proceed on pilot training, the candidate had to achieve both an acceptable pilot aptitude index at CFASC and to have met the medical standard for pilot in the CF.

Table 8. CFASC/CMB Testing 1979-1989

	Females (N=604)	Males (N=2905)
SUCCESSFUL - Pilot	118	1043
SUCCESSFUL - Nav	79	411
UNSUCCESSFUL	407	1451
Pilot Success Rate -	19.5%	35.9%

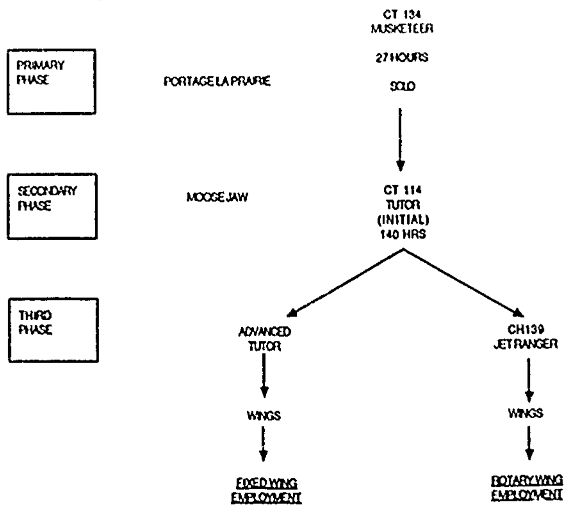
*The male totals are for the years 1987-1989. The female success rate for those 3 years only is 16.4% (N=379)

The data presented is based on anglophone candidates; female francophone candidates have not done as well. There has been no significant sex difference in the success rate for navigator.

Training

In November 1979, the first four female pilot trainees began 15 months of pilot training as depicted in figure 1.

Figure 1. CF Pilot Training Scheme



Primary flying training is conducted at Canadian Forces Base (CFB) Portage La Prairie, Manitoba on the CT 134 Musketeer, a low-wing monoplane piston aircraft manufactured by the Beech Aircraft Corporation. Successful students than proceed to CFB Moose Jaw in Saskatchewan where all students do initial training on the CT 114 Tutor, a completely aerobatic turbo-jet aircraft. Those proceeding to fixed-wing employment complete their training reaching WINGS standard on the Tutor. Students selected for rotary-wing employment break-off and return to CFB Portage La Prairie for basic rotary-wing training reaching WINGS standard on the CH 139 Jet Ranger, a light helicopter. During the trial period, it was the opinion of a significant number of males that selection and training standards were lowered for women, but there is no real evidence for this. In a review of aptitude scores achieved by succesful candidates at CFASC 1979-1981, it was determined that 20 of 494 male trainees (4.1%) and 4 of 74 female trainees (5.4%) had a lower than desirable pilot aptitude index.[4] Given the small number of female trainees, it is considered that the same CFASC standards were used. As with males, the success rate in training does vary from course to course and some individuals take longer to reach wings standard than others. Table 9 summarizes a review of statistics compiled since 1979 and, although the female numbers are few as compared with males, one cannot make any claim for a significant sex difference in success rate.

Table 9. Success Rate of Females Versus Males in Aircrew Training 1980 - 1988

	Females		Males	
COURSE	N	Successful	N	Successful
Pilot Primary Basic Flying Training CT 134	56	39 (70%)	2677	1798 (67%)
Pilot Basic Flying Training CT 114	25	20 (80%)	1568	1257 (80%)
Pilot Advanced Flying Training CT 114	5	4 (80%)	448	431 (96%)
Pilot Rotary Wing Basic	12	11 (92%)	817	801 (98%)
Navigator Basic	13	9 (69%)	446	371 (83%)

Note. 6 females achieved Flight Engineer Status

The flight surgeon at Moose Jaw, who is also a pilot, has noted that most females have gone the Rotary Wing route in training rather than the Advanced Tutor course over the past 3-4 years. His observation is that they tend to be more methodical but generally less aggressive in their approach to flying and it could be postulated that females generally have somewhat less ability or lower motivation for high performance jet flying. It is an observation deserving of further study.

Current Employment

As of September 1989, there were 19 qualified female pilots in the Canadian Forces serving with their male counterparts in all areas of the Air Force. Table 10 lists their employment situations at that time. There are also some 56 females presently in training.

Table 10. Employment of Female Aircrew

	Pilots	Navs	Flt Eng
Tactical Fighter Squadron - CF 118	2		
Transport Squadron CC 130 & Challenger	4		3
Tactical Helicopter Squadron	1		
Light Transport - Search and Rescue (RW)	4		1
Flying Training	3		
Maritime Patrol Squadron		1	
Staff Positions	5	5	

Males usually shun staff positions for as long as possible. An interesting comment by a female personnel research officer was that married female pilots are quite receptive to staff positions earlier in their career as it does allow them time to complete other aspects of their life planning 'Check List' such as becoming pregnant.

CONCLUSIONS

Much larger numbers of males than females continue to apply for aircrew training in Canada. Selection test data over a 10 year period indicate that females score significantly lower in quantitative and spatial/psychomotor skills; as long as the Pilot job task emphasizes these skills, proportionately fewer females will be selected for training. Medical assessment data does indicate that a greater number of females will fail to meet the medical standard for pilot. The only reason for the difference is in the area of anthropometry. Again, as long as military cockpits are designed primarily with male indices, a greater number of females will continue to be excluded. Experience over the period has demonstrated that appropriately selected female aircrew, that is, using the same standards as for males, can perform equally with their male peers during training and in operational flying in the Air Force.

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TITRE : Sélection, formation et emplois opérationnels des pilotes féminins dans l'Armée de l'Air et l'Aviation Légère de l'Armée de Terre en France.

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RESUME :

Depuis 1982, les forces armées françaises recrutent des pilotes féminins. Le but de ce travail est de relater l'expérience de l'Armée de l'Air (AA) et de l'Aviation Légère de l'Armée de Terre (ALAT) depuis 1983 et 1982 respectivement en matière de sélection, formation et emploi opérationnel de ces personnels.

La sélection est sévère : 24 candidates retenues sur 620 testées pour l'ALAT, 25 sur 900 pour l'AA. Les critères de sélection, techniques et médicaux, sont les mêmes que pour les hommes. Les causes d'élimination ne sont pas différentes. Le déroulement de la formation et les échecs en école de pilotage sont identiques pour les deux sexes.

Dans l'AA, les pilotes féminins sont affectés exclusivement dans les emplois du transport aérien, à l'exclusion des vols tactiques ; dans la limite des 10 % des effectifs, 15 pilotes féminins (12 d'avions de transport, 2 d'hélicoptères, 1 moniteur) sont actuellement en service.

Dans l'ALAT, depuis 1986, tous les emplois sont ouverts aux femmes, dans la limite de 3,5 % des effectifs ; 18 pilotes sont en service : 6 dans un régiment d'hélicoptères de combat, 2 pilotent des hélicoptères de manoeuvre, 10 des hélicoptères légers, dont une commande une escadrille.

Différentes difficultés sont rencontrées mais aucune pathologie spécifique n'a été relevée. En ce qui concerne l'ergonomie, la taille et les mensurations segmentaires posent quelques problèmes pour certains appareils et dans certaines conditions de vol.

En ce qui concerne la grossesse (6 cas), la seule difficulté réelle est l'obligation d'effectuer un stage de requalification après une année d'interruption. Notre expérience est trop récente pour tirer des conclusions à propos des changements de motivation après maternité, qui semblent néanmoins réels.

En ce qui concerne l'intégration dans les unités opérationnelles, les équipages sont mixtes. Après quelques difficultés au cours des deux premières années (marginalisation ou phénomène de vedettariat), l'intégration des femmes pilotes est actuellement satisfaisante.

1. INTRODUCTION

Au cours du deuxième conflit mondial, les armées françaises réquisitionnèrent des pilotes féminins pour des missions de convoyage d'avions. Une tentative de création d'un véritable corps de pilotes militaires féminins prit fin brusquement en juillet 1946. Il faut alors attendre la décennie 80 pour voir un nouvel essai de recrutement ; 1982 pour l'ALAT et 1983 pour l'AA. L'objet du travail que nous présentons est de rapporter les modalités et les résultats de la sélection, de la formation et des emplois opérationnels des pilotes féminins de ces deux armées, et de tenter de tirer les enseignements de cette courte expérience.

2. LES METHODES

Nous avons exploité différentes sources d'informations :

- les textes réglementaires relatifs aux divers aspects du sujet,
- l'anamnèse professionnelle et médicale des intéressées ainsi que l'étude de leurs dossiers médicaux,
- l'écoute des différents échelons des commandements concernés,
- les réponses à un questionnaire anonyme que nous avions adressé à chaque pilote féminin en activité.

3. LES RESULTATS

3.1. Le recrutement

Aspects juridiques et évolution

S'abritant derrière la notion de combat, les armées excluaient les personnels féminins des emplois jugés exposés . Les décrets du 22 décembre 1975 (1) stipulent en effet : "en raison des conditions de mise en oeuvre et d'intervention des unités de combat, les emplois.... d'officiers des armes... de sous-officiers de carrière dans les armes.... les emplois du personnel navigant.... ne sont ouverts qu'aux hommes."

En 1981, le Ministre de la Défense décide d'ouvrir, à titre expérimental, la spécialité de pilote de l'ALAT aux personnels féminins (2). Il est précisé qu'au plan de l'emploi ces personnels devront être spécialisés dans le pilotage des appareils de liaisons ou d'évacuation sanitaire. Le recrutement devra porter en 1982 sur un officier et trois sous-officiers issus des forces. Ultérieurement, la féminisation sera réglementairement limitée à 3,5 % des effectifs globaux recrutés annuellement, soit un quota de 3 à 4 personnels féminins par an.

Fin décembre 1981, le Ministre de la Défense crée une commission d'étude prospective de la femme militaire. Les conclusions de cette commission devront servir de base aux mesures que le gouvernement prendra en faveur de l'intégration des femmes dans les armées. C'est ainsi qu'à son tour l'Armée de l'Air recrutera, pour une période probatoire, des pilotes féminins ; leur nombre sera limité, de même que le domaine de leur emploi. Les décrets du 10 mars 1983 (3) modifient dans ce sens ceux du 22 décembre 1975 cités plus haut : "en raison des conditions de mise en oeuvre et d'intervention des unités de combat, les emplois du personnel navigant ouverts aux femmes sont limités au transport aérien militaire. Le recrutement du personnel navigant féminin est limité à 10 % du nombre de brevets de pilote militaire délivrés l'année précédente au titre du transport aérien militaire." En 1983, l'Armée de l'Air offre alors 4 places à des candidates qui pourront accéder à la carrière de pilote militaire par le biais des élèves officiers du personnel navigant à vocation d'officiers de réserve en situation d'activité (4). Le concours d'admission à l'Ecole de l'Air de SALON-DE-PROVENCE qui permet l'accès direct au corps des officiers de l'Air n'est toujours ouvert qu'aux hommes. Toutefois, "les femmes titulaires du brevet de pilote militaire du second degré auront accès à ce corps... pour occuper des emplois (de commandement) dans le transport aérien militaire" et cela par le biais du concours d'admission à l'Ecole Militaire de l'Air.

En 1985, l'Armée de Terre va encore plus loin ; dans des arrêtés en date du 31 mars 1985 (5), le Ministre de la Défense lève les restrictions d'emploi : "Les officiers féminins... les sous-officiers féminins... peuvent tenir tous les emplois en état-major et en école ainsi que ceux des formations des armes... Les emplois sont dévolus aux officiers... sous-officiers.... masculins et féminins selon les mêmes critères d'aptitude". Ainsi les pilotes féminins de l'ALAT ont désormais accès à tous les emplois de pilote y compris pilote de combat.

3.2. La sélection initiale

Elle est psychotechnique et médicale.

3.2.1. La sélection initiale dite psychotechnique

Le contenu des épreuves de sélection est identique pour les garçons et les filles.

Les modalités sont légèrement différentes selon l'armée.

Au Centre de Sélection de l'Armée de l'Air de BRETIGNY, au cours d'une session annuelle réservée aux candidates âgées de 17 à 22 ans, toutes de niveau général baccalauréat minimum, sont effectués :

- des tests dits papier-crayon (compréhension de lecture, principes mécaniques, orientation spatiale, lectures de cadrans, etc...) évaluant le niveau général et les aptitudes techniques ;

- un test type contrôle de palonnier d'évaluation de la coordination psychomotrice ;

- une épreuve sur plate-forme d'évaluation d'aptitude au pilotage (depuis 1985) testant la capacité de division de l'attention en environnement stressant ;

- des entretiens (depuis novembre 1985) avec un médecin psychologue puis deux officiers pilotes jugeant essentiellement la motivation et la capacité d'adaptation ;

- des épreuves sportives banales (course à pied, lancer de poids, grimper de corde, natation). Le barême de notation est adapté au sexe et les épreuves peuvent être recommencées après entraînement en cas de résultat insuffisant (note inférieure à 6/20) ;

- un test en langue anglaise qui peut lui aussi être repassé en cas d'échec ;

L'Antenne de sélection de l'ALAT du Fort Neuf de VINCENNES n'organise pas de session spéciale. Les filles sont recrutées soit au niveau baccalauréat, soit au niveau BEPC. Elles effectuent :

- des tests psychologiques d'évaluation de la personnalité ;

- des épreuves en plate-forme de simulation de pilotage et des tests psychotechniques permettant de porter un pronostic de réussite en école de pilotage ;

- des entretiens avec un médecin psychologue et un officier pilote dont la synthèse donne un pronostic d'adaptation générale à l'emploi.

3.2.2. La sélection médicale

3.2.2.1. Les normes

Les candidates subissent une visite médicale d'admission dans un Centre d'Expertise Médicale du Personnel Navigant.

Elles doivent satisfaire aux normes d'admission "candidat pilote de transport ou hélicoptère" définies dans l'instruction 3700/2/DCSSA/AST du 3 novembre 1967 modifiée. Les normes sont identiques pour les filles et les garçons, en particulier les normes anthropométriques. La taille minimale exigée est de 1,60 mètre. Seul l'article 16bis est spécifique : "Le personnel féminin ne doit pas présenter dans le domaine gynécologique de troubles ou de séquelles d'intervention pouvant le gêner dans l'exercice de ses fonctions ou compromettre la sécurité. La grossesse entraîne l'inaptitude temporaire.

Les standards "aviation" minima exigés sont différents pour l'AA et l'ALAT :

- Candidat pilote de transport ou hélicoptère (AA)

SGA	SVA	SCA	SAA
1B	2	1	1

- Candidat pilote de l'ALAT (instruction n° 3300/DEF/EMAT/EMPL/AA et n° 350/DEF/EMAT/BEP/P du 25 février 1987)

SGA	SVA	SCA	SAA
2B	2	1	2

3.2.2.2. Les causes d'inaptitude médicale

Nous avons étudié la population des candidates de l'AA car elle est sélectionnée dans un même centre d'expertise, ce qui rend les résultats plus homogènes.

ARMEE DE L'AIR DE 1983 A 1988 INCLUS

27 candidates éliminées pour 29 causes d'inaptitude médicale
2 candidates ont deux causes d'élimination

Cause visuelle SVA.................... 17
Cause médicale générale SGA........... 11
Cause auditive SAA.................... 1

TOTAL.................. 29

Causes visuelles = 17

SVA 0 = 3 SVA 3 = 11 SVA 4 = 1 SVA 5 = 2

Myopies = 10 dont 8 myopies objectives
Astigmatisme = 2
Trouble de la vision binoculaire = 3
Anomalie du fond d'oeil = 2

Causes médicales générales = 11

SGA 0 = 11

Taille inférieure à 1,60 m = 3
Anomalie EEG lors de la SLI = 3
Prolapsus valvulaire mitral = 1
Extrasystolie ventriculaire = 1
Syndrome du défilé costoclaviculaire = 1
Intolérance aux hydrates de carbone = 1
Anomalie du rachis = 1

Cause auditive

SAA 2 = 1
Hypoacousie de perception = 1

Pour ce qui concerne l'ALAT, 11 candidates ont été éliminées pour causes médicales mais 4 visites n'ont pas été terminées par abandon volontaire des intéressées. Sur les 7 restantes, 2 étaient déclarées inaptes temporaires mais ne se sont jamais représentées en expertise.

7 éliminations = - 3 pour cause visuelle
- 4 pour cause générale

3.3. La formation

A l'issue de la sélection initiale et de la sélection médicale, les commandements concernés exercent leur choix parmi les candidates présentant les meilleures aptitudes.

3.3.1. Les modalités

3.3.1.1. Pour l'AA, la formation comporte trois étapes avant la remise du brevet de pilote militaire :

- La première est en fait une véritable sélection en vol effectuée à l'Ecole de Formation Initiale du Personnel Navigant à AVORD au cours de 12 vols sur avion à hélice CAP10. C'est à ce niveau également que s'exerce les numerus clausus.

- La seconde est une formation au pilotage de base complétée par une préspécialisation transport effectuée au Groupement Ecole 315 de COGNAC pendant huit mois et comprenant respectivement 100 et 20 heures de vol sur avion TB30 Epsilon.

- La troisième est la spécialisation transport effectuée au Groupement Ecole 319 d'AVORD comprenant 106 heures de vol sur bimoteur Xingu en 7 mois. Le pilote a une formation de base complète (vol aux instruments, vol de nuit, basse altitude).

Après la remise du brevet, elle est parachevée au Centre d'Instruction des Equipages de Transport ou d'Hélicoptères à TOULOUSE puis en unité.

3.3.1.2. Pour ce qui concerne l'ALAT, la formation initiale comporte une seule phase avant la délivrance du brevet vol à vue.

- Le pilotage de base à l'Ecole de Spécialisation ALAT de DAX d'une durée de 6 mois ou 120 heures de vol sur Alouette II puis Gazelle en fin de stage après remise du brevet.

- Un stage de formation complémentaire au vol tactique à l'Ecole d'Application de l'ALAT du LUC-EN-PROVENCE pendant 2 mois est effectué après un an passé en unité. Ce stage peut être recommencé en cas d'insuffisance. Il donne la qualification pilote de combat. De même, la qualification vol aux instruments est délivrée en cours de carrière.

3.3.2. Les causes d'échec

3.3.2.1. Pour ce qui concerne l'AA, 15 élèves pilotes féminins ont été éliminées, toutes à la première phase de sélection en vol :

- 3 techniquement bonnes en vol mais victimes de la rigueur du numerus clausus,

- 12 pour insuffisance technique en vol jugée sur 15 critères.

Les facteur d'élimination les plus importants et les plus fréquemment retrouvés sont : la rigueur 12 fois ; la division de l'attention 10 fois ; la visualisation 12 fois ; l'aptitude à assimiler 11 fois ; ce sont les mêmes que l'on retrouve à l'origine de l'élimination des garçons.

3.3.2.2. Pour ce qui concerne l'ALAT, les éliminations se sont faites au stade du pilotage de base à DAX. On compte 4 échecs :

- 1 officier pour cause "médicale" : inadaptation primaire au vol,
- 3 sous-officiers pour insuffisance technique au vol.

Les facteurs d'élimination retrouvés sont :

- le manque de décision de l'attention = 3 fois
- la lenteur d'analyse de la situation = 2 fois
- le manque de résistance physique = 1 fois.

3.3.3. Le bilan chiffré

ARMEE DE L'AIR

	NOMBRE DE CANDIDATES TESTEES	ADMISES A L'ECOLE DE FORMATION INITIALE DU PN	ADMISES EN ECOLE DE PILOTAGE DE BASE
1983	143	4	4
1984	170	4	4
1985	148	4	4
1986	135	9	2

1987	101	6	2
1988	107	8	4
1989	96	7	5
TOTAL	900	42	25

AVIATION LEGERE DE L'ARMEE DE TERRE

	NOMBRE DE CANDIDATES TESTEES	NOMBRE DE CANDIDATES ADMISES EN PILOTAGE DE BASE
1982	42	3
1983	49	3
1984	73	4
1985	169	4
1986	89	4
1987	103	3
1988	88	3
1989	66	4
TOTAL	679	28

3.4. L'emploi opérationnel et la vie en unité

3.4.1. Descriptif des emplois tenus

Dans l'AA, les pilotes féminins servent en tant qu'officier de réserve en situation d'activité. Ce contrat permet d'effectuer une carrière de vingt années. Mais l'obtention du congé du personnel navigant et le bénéfice d'une pension de retraite à jouissance immédiate peuvent être accordés de plein droit au bout de 15 ans de service dont 6 en qualité de navigant. L'activation en qualité d'officier de carrière est possible par le biais du concours de l'Ecole Militaire de l'Air, elle permet l'exercice du commandement. Initialement limité au transport logistique (liaisons, évacuation sanitaire), l'emploi a été étendu à celui de moniteur (transport).

Le Transport Aérien Militaire (logistique + tactique)
c'est 600 pilotes dont 55 nouveaux tous les ans

De 1983 à fin 1989, 16 pilotes féminins ont été brevetés et 3 sont en cours de formation, un a rompu son contrat.

Les emplois tenus

10 pilotes féminins servent au sein de 4 escadrons de transport et d'entrainement différents soit de 1 à 5 personnels féminins sur 16 pilotes par escadron.
2 servent au sein de 2 escadrons d'hélicoptères différents.
1 sert au sein d'un escadron d'expérimentation et de transport appartenant au Centre d'Expérimentations Aériennes Militaires.
1 est moniteur dans un Groupement Ecole du Commandement des Ecoles de l'Armée de l'Air.
1 est admise à l'Ecole Militaire de l'Air.

Les appareils utilisés

- Nord 262 Frégate, MS71 PARIS, Xingu
- Alouette III, Ecureuil.

Dans l'ALAT, les personnels féminins sont officiers ou sous-officiers de carrière ou sous contrat. Dans ce dernier cas, ils s'engagent à servir 10 ans à l'issue du stage de pilotage, ou 8 ans lorsqu'il s'agit d'un recrutement interne "militaire".

Aujourd'hui tous les types d'emploi leur sont réglementairement ouverts.

L'ALAT, c'est 1280 pilotes (465 officiers + 815 sous-officiers)
100 pilotes nouveaux tous les ans

De 1982 à 1989, 18 pilotes féminins ont été formés (4 officiers et 14 sous-officiers)

Les emplois tenus

10 pilotes d'hélicoptères légers
2 pilotes d'hélicoptères de manoeuvre
6 pilotes d'hélicoptères de combat
(une chef de patrouille
une seulement a effectué le stage tir canon)

1 officier a reçu le commandement d'une escadrille d'hélicoptères légers.

Appareils utilisés

Alouette, Puma, Gazelle.

3.4.2. Les difficultés physiques du pilotage

3 pilotes de l'AA et 2 de l'ALAT ont fait part de difficultés physiques au pilotage. Elles sont liées soit à l'anthropométrie (petite taille, petit gabarit), soit à un manque de force physique et souvent à la combinaison des deux.

Il s'agit de difficultés d'atteinte des commandes, de contention insuffisante malgré un brêlage serré, de difficultés d'action aux palonniers en certaines circonstances et de manque de force physique en cas de panne des servo-commandes.

3.4.3. Pathologie rencontrée et exemptions de vol

Liée au vol (année 1989) : 3 cas de mal de l'air se manifestant lorsque les intéressées ne sont pas aux commandes

1 otite barotraumatique (8 j. d'exemption de vol)
2 cas de règles plus douloureuses lors des vols avec difficultés de concentration.

Non liée au vol (année 1989)

- Aucune exemption de vol supérieure à un mois en 1989 pour l'AA, 3 pour l'ALAT pour la pathologie suivante : kyste pilodinal opéré, fracture du membre supérieur, hépatite virale.

- Recours à un service spécialisé de psychologie en clinique : en 8 ans aucun cas de difficulté d'adaptation d'ordre psychologique n'a nécessité le recours à une consultation spécialisée parmi les pilotes féminins de l'AA. En revanche, cette éventualité est survenue chez 2 pilotes de l'ALAT. Pour le premier, il s'agit de l'inadaptation primaire au vol que nous avons mentionnée plus haut.

Pour cet officier qui sert depuis 6 ans dans l'arme du matériel où elle ne trouve pas particulièrement ce qu'elle attend de la vie militaire, l'ouverture des emplois de pilote apparaît comme une seconde chance. Malgré un pronostic défavorable à la sélection initiale (antécédents de spasmophilie, de cinétose, peu sportive, formation littéraire), elle est admise en école de pilotage car il s'agit de la première année du recrutement et l'on souhaite former un officier. Ce sera un échec très rapide et cette candidate malheureuse développera par la suite un syndrome dépressif majeur nécessitant six mois de traitement spécialisé.

Pour le second, il s'agit d'un syndrome anxiodépressif avec épisodes douloureux abdominaux atypiques dont le point de départ semble avoir été le décès de son compagnon dans un accident d'avion. Loin de sa famille et de ses amis, l'état affectif de cette jeune femme s'aggrave et les difficultés au sein de l'escadrille s'accumulent jusqu'au jour où elle n'est plus jugée comme un pilote fiable. Après soutien psychothérapique, cet épisode a régressé et l'intéressée a repris les vols.

3.4.4. La grossesse

A ce jour, l'on comptabilise 4 grossesses pour les personnels de l'ALAT et 2 pour les personnels de l'AA. Aucun problème médical n'a été rencontré.

Dès l'état de gestation constaté, l'exemption de vol est règlementaire. Après l'accouchement, la reprise des vols n'est possible qu'après visite médicale d'aptitude passée dans un Centre d'Expertise Médicale du Personnel Navigant.

A l'issue de leurs grossesses, tous les pilotes féminins ont repris leurs activités aéronautiques cependant deux (1 de l'AA et 1 de l'ALAT) ont présenté des difficultés de réadaptation ; l'investissement maternel étant très important pour elles.

3.4.5. L'intégration au sein de l'escadron

Des difficultés d'intégration ont été péniblement ressenties par 5 pilotes féminins de l'AA ainsi que par 5 de l'ALAT.

Les griefs invoqués sont :

- l'impression désagréable d'être l'objet de curiosité,
- d'avoir à prouver en permanence leur aptitude professionnelle de pilote militaire,
- d'être l'objet de jalousie,
- d'être victimes de misogynie ou de "machisme".

3.5. Autres résultats tirés de l'exploitation du questionnaire anonyme

L'exploitation du questionnaire anonyme permet de dégager quelques tendances concernant la motivation, les aspirations, l'appréhension des contraintes liées au métier de pilote militaire. Compte tenu de la faiblesse de l'effectif, le petit nombre des réponses (9 pour l'AA, 9 pour l'ALAT), il s'agit plus d'une enquête d'opinion, d'une photographie, que d'un travail à valeur scientifique et statistique.

LES MOTIVATIONS

	Armée de l'Air	ALAT
Motivation militaire prédominante	5	0
Motivation aéronautique prédominante	3	5
Motivation mixte	1	4
Avaient envisagé une carrière aéronautique civile	4	7
N'avaient pas envisagé une carrière aéronautique civile	5	2
Avaient pris connaissance des statuts avant l'engagement	5	5
N'avaient pas pris connaissance de statuts avant l'engagement	4	4
Avaient pris connaissances des perspectives d'emplois et de carrière avant engagement	4	5
N'avaient pas pris connaissance des perspectives d'emplois et de carrière avant engagement	5	4

Sur l'ensemble des réponses, on constate une très légère prédominance de la motivation militaire chez les candidates de l'AA où la primauté des valeurs militaires et morales traditionnelles est clairement exprimée (patriotisme, don de soi, défense de la nation). La motivation des candidates ALAT est davantage technique, aéronautique ; la major'té d'entre elles avaient d'ailleurs envisagé une carrière aéronautique civile.

Pour deux candidates de l'AA, l'attrait pour un métier hors du commun pour une femme et pour l'une d'elle la fascination de l'aviation de guerre a joué un rôle déterminant.

Aussi bien pour l'AA que pour l'ALAT, la moitié des candidates n'a pas pris connaissance des statuts et des perspectives d'emplois et de carrière avant l'engagement (à propos de ce dernier point, les perspectives offertes par l'AA n'étaient pas très précises au début de l'expérience).

EMPLOI ET VIE FAMILIALE

		Armée de l'Air	ALAT
Pensez-vous que l'emploi de pilote militaire est compatible avec une vie de couple satisfaisante ?	OUI	8	7
	NON	1	2
Pensez-vous que l'emploi de pilote militaire est compatible avec une vie de mère de famille satisfaisante ?	OUI	2	4
	NON	4	5
	Pas de réponse	3	0
Pensez-vous qu'avoir un enfant puisse retentir sur la motivation aéronautique ?	OUI	4	4
	NON	5	5
Jusqu'au point d'interrompre la carrière ?	OUI	4	4
	NON	5	5

L'emploi de pilote militaire apparaît largement comme compatible avec une vie de couple satisfaisante avec cependant parfois la restriction que le compagnon connaisse bien les servitudes militaires.

L'opinion est très partagée quant à la question de la compatibilité de l'emploi et d'une vie de mère de famille satisfaisante et d'un retentissement de la maternité sur la motivation aéronautique.

LES DESIDERATA

		Armée de l'Air	ALAT
Etes-vous actuellement satisfaite de vos conditions d'emploi ? de travail ?	OUI	2	4
	NON	7	5

L'insatisfaction importante qui se dégage dans l'AA apparaît très liée à la restriction d'emploi. La majorité des pilotes demande l'ouverture du transport aérien tactique et de l'emploi outre-mer pour les volontaires. Une pilote exprime un désiderata particulier : la création d'un escadron complètement féminisé à vocation de liaisons et d'EVASAN.

Pour ce qui concerne l'ALAT, les insatisfactions exprimées sont moins nombreuses et d'un ordre différent.

Les charges militaires extra aéronautiques dites annexes (gardes, tours de service, instruction) sont jugées excessives.

		Armée de l'Air	ALAT
Pensez-vous que la fonction de pilote d'avion de combat soit accessible aux femmes ?	OUI	9	8
	NON	0	1
Aimeriez-vous exercer ce métier ?	OUI	4	9
	NON	5	0

La réponse est quasi unanime. Rien ne semble s'opposer physiologiquement et techniquement à ce qu'une femme particulièrement résistante et douée soit pilote de combat. L'obstacle cité le plus souvent comme majeur est la réaction, jugée a priori défavorable, des pilotes de combat masculins. Une fois est mentionné l'aspect psychologique de la capacité à tuer.

Quant à l'attrait pour le métier de pilote de combat, il est très fort pour les personnels ALAT, beaucoup plus modéré pour les pilotes féminins de l'AA.

4. COMMENTAIRES

4.1. Recrutement

En France, la féminisation des emplois de pilotes militaires s'est faite, pour l'essentiel, sous une pression politique résultant de la dynamique égalitaire et non en raison de difficultés du recrutement masculin. La limitation quantitative avait pour but de permettre une expérimentation réaliste tout en laissant une période probatoire suffisante à l'adaptation des unités et des personnels masculins à cette révolution. Les restrictions qualitatives d'emploi participaient à ce souci mais également à celui de minimiser le risque financier (coût de la formation) en cas d'échec.

Un recrutement suppose une ressource suffisante et de qualité. Au début de l'expérience, l'appel d'offre a été lancé dans la population féminine déjà engagée (pour l'ALAT celle ayant entre 6 et 11 ans de carrière) dont on pouvait supposer la motivation militaire solide et l'intégration facile. En fait le volontariat pour servir au titre du personnel navigant a été pour beaucoup de ces femmes une deuxième chance d'avoir la vie active dont elles rêvaient mais qu'elles n'avaient pas trouvé dans l'exercice de leur emploi antérieur. Rapidement cette ressource s'est révélée trop limitée quantitativement ; souvent par le fait que la situation familiale des candidates potentielles (mariées, enfants à charge) allait à l'encontre de la disponibilité exigée, ce fut particulièrement vrai pour l'ALAT. Aussi l'appel d'offre a été élargi à la population civile âgée de 17 à 22 ans de niveau baccalauréat pour l'AA, baccalauréat ou BEPC pour l'ALAT. Malgré cette extension, les chiffres montrent une chute d'un tiers des demandes de candidatures puis une stabilisation à ce niveau à partir des années 1986-1987. On peut expliquer cela par l'émoussement de l'attrait de la nouveauté ainsi que par une meilleure connaissance, au départ, des difficultés du métier et des perspectives de carrière. Néanmoins la ressource demeure suffisante pour assurer le recrutement de qualité aussi bien pour ce qui concerne l'AA que l'ALAT où l'on retient en moyenne 4 candidates pour 100 testées. Pour l'avenir, la situation risque d'évoluer ; les compagnies aériennes recrutant énormément et à des niveaux d'instruction générale plus modeste qu'auparavant. A cet égard, les réponses au questionnaire sur la motivation laissent présager un certain transfert vers l'aéronautique civile.

4.2. Sélection initiale psychotechnique

En France nous utilisons les mêmes tests, les mêmes épreuves pour les filles et les garçons. Ceci se conçoit aisément puisque l'on recherche les mêmes qualités, les mêmes aptitudes. La critique que l'on peut émettre concerne le numerus clausus qui permet d'offrir systématiquement un certain nombre de places aux filles même si elles sont moins bonnes, dans l'absolu, que des garçons et, a contrario, d'éliminer certaines des meilleures candidates.

Une deuxième remarque a trait aux difficultés relevées par les testeurs lors de l'épreuve en plate-forme de simulation au centre ALAT et lors de l'épreuve type contrôle de palonniers au centre de l'AA. Lors de ces tests, les candidates de petite taille ont presque systématiquement des scores médiocres. Existe-t-il un handicap spécifiquement féminin ou bien est-il seulement en relation avec la plus petite taille des candidates ? Dans la mesure où la dimension de cette plate-forme, ou la force à exercer sur les commandes sont représentatives de la réalité, et c'est le cas, ce fait doit être pris en compte globalement. On peut par ailleurs penser qu'il supplée l'absence de test physique spécifique des emplois aéronautiques comme le test américain "across the board strength test".

4.3. Sélection initiale médicale

Les mêmes procédures de sélection et les mêmes normes sont appliquées pour les filles et les garçons, ce qui paraît dicté par le bon sens. Les causes d'inaptitude observées sont superposables pour les deux populations tant pour ce qui concerne la nature que le pourcentage relatif ; les anomalies visuelles arrivant en tête et de loin.

Certains jugent discriminatoire le fait d'exiger pour les candidats EOPN masculins de l'AA la norme SGA 1A alors que les candidates EOPN doivent seulement satisfaire à la norme SGA 1B. En fait, il faut bien voir qu'il s'agit de sélectionner deux populations distinctes bien qu'ayant le même statut ainsi qu'une formation de base commune. Les garçons ont, au départ, tous vocation à devenir pilote de chasse, d'où l'exigence d'une aptitude siège éjectable.

4.4. La formation

Les élèves pilotes se retrouvent en promotion mixte pour recevoir une instruction standard. Les moniteurs de début sont tous masculins aussi bien pour l'AA que pour l'ALAT, de même que les moniteurs de spécialisation transport jusqu'à une date récente. En Groupement Ecole transport, les binomes d'élèves pilotes sont toujours mixtes, un garçon, une fille. Nous n'avons relevé aucun problème majeur à ce niveau. L'intégration des candidates a été satisfaisante et même excellente dans la majorité des cas. Quant aux moniteurs, initier et former des pilotes féminins ne leur a pas causé de difficultés psychologiques insurmontables.

En vol, aucun comportement spécifiquement féminin n'a été relevé. Les cas d'échec ne sont pas plus nombreux ; ils seraient même inférieurs, mais la comparaison est difficile car si la sélection initiale est identique dans son contenu, elle est différente dans ses modalités et les deux populations ne sont pas comparables. Nous pouvons néanmoins noter que les défauts incriminés en cas d'insuffisance technique en vol sont par ordre de fréquence les mêmes que chez les garçons.

4.5. L'emploi opérationnel

4.5.1. Les effectifs

Les 15 pilotes féminins en activité opérationnelle dans l'AA représente 2,6 % de l'effectif pilote du Transport Aérien Militaire. L'emploi étant restreint aux vols de liaison et d'évaucations sanitaires, certains escadrons privilégiés (VILLACOUBLAY, METZ) peuvent voir néanmoins leur effectif féminisé au tiers (3/16, 5/16).

Mais la plupart des escadrons ne compte en général qu'un seul pilote féminin. Il résulte de ce fait et du caractère récent de l'expérience que l'occasion de constituer un équipage de transport entièrement féminin (commandant de bord et second pilote) demeure exceptionnelle.

Pour ce qui concerne l'ALAT, le taux global de féminisation est plus faible, les 18 pilotes féminins en activité opérationnelle représentent 1,4 % de l'effectif pilote total. Dans la plupart des cas, la proportion de femmes pilotes est de 2 par régiment.

En résumé, le risque de mise à l'écart, de marginalisation des pilotes féminins s'il est moindre qu'au début de l'expérience, est encore potentiellement présent dans bon nombre d'escadrons.

4.5.2. Les emplois

L'AA, sans lever les restrictions d'emploi initiales, a étendu avec succès la féminisation en juillet 1986 aux escadrons d'hélicoptères et à certaines unités hors transport aérien proprement dit. Ceci permet une meilleure souplesse dans la gestion du personnel, ainsi qu'une diversification des affectations géographiques. De même dans ce souci de diversification, des emplois de moniteur pilote de transport ont été ouverts. L'intérêt pédagogique, par la possibilité d'identification à leurs aînées donnée aux jeunes élèves féminins, était par ailleurs bien compris. Cette expérience n'est actuellement pas concluante, c'est peut-être une question d'individualité, nous en reparlerons plus loin.

L'ALAT, quant à elle, a ouvert tous ses emplois aux pilotes féminins y compris celui de pilote de combat. En pratique, plusieurs pilotes féminins servent dans des unités opérationnelles et s'entraînent pour des missions qui seraient très exposées au feu ennemi. Une seule cependant a reçu, à l'heure actuelle, une instruction de tir au canon et est donc devenue apte au maniement de la force armée au service de la nation.

4.5.3. Difficultés physiques au pilotage

Nous l'avons vu, ces difficultés ne sont rencontrées que chez les pilotes féminins de petit gabarit. Sont-elles spécifiques aux femmes ou communes aux hommes de même stature ? Quoiqu'il en soit, cet état de fait n'est pas satisfaisant au regard de la sécurité des vols. Outre la mise au point d'un test de force spécifiquement aéronautique (actions sur des gouvernes non asservies par exemple), deux types d'action complémentaires mériteraient d'être menées à l'avenir : amélioration du réglage des sièges, encore très différent selon le type d'appareil, et meilleure prise en compte de l'ergonomie des cabines existantes pour la détermination des normes anthropométriques requises. Exiger une taille minima de 1,60 mètre n'est pas suffisant. Il faut également tenir compte des mesures segmentaires et à ce niveau il semble que les femmes soient, dans l'ensemble, désavantagées par rapport aux hommes.

4.5.4. Difficultés d'intégration

Les réponses au questionnaire montrent qu'un certain nombre de pilotes féminins ont rencontré et rencontrent encore des difficultés d'intégration, éprouvent la sensation désagréable d'être observées en permanence, d'être jalousées. Si dans l'ensemble les pilotes masculins reconnaissent la compétence technique de leurs collègues féminines, ils leur reprochent souvent un manque de motivation militaire, un manque de disponibilité, voire un absentéisme important. Le problème est davantage placé sous l'angle des relations humaines que sous celui de l'aptitude professionnelle pure. L'introduction de femmes dans un milieu traditionnellement masculin engendre toujours ce genre de phénomènes car il remet en question la supériorité supposée des hommes, dérange les habitudes, modifie la dynamique du groupe. L'adaptation et l'intégration est lente, difficile et les moindres faux-pas sont exploités pour justifier une attitude de rejet. Il fallait donc s'attendre à rencontrer des difficultés lors de la féminisation des emploi de pilotes militaires en France. Elles ont été d'autant plus aiguës que l'on a commis un certain nombre d'erreurs au début de l'expérience.

D'abord celle de disperser les femmes dans différents escadrons favorisant leur marginalisation. Ensuite de laisser, dans certains cas, se développer un favoritisme pour ce qui concerne les servitudes militaires. Enfin et surtout, de n'avoir pas su maîtriser le phénomène de "vedettariat". Ayant vocation au transport des personnalités, des "V.I.P.", on a pu ainsi voir revenir de mission tel pilote avec un bouquet de fleurs ou bien encore telle personnalité réclamer avec insistance d'être transporté par un pilote féminin. La féminisation se devait d'être médiatisée. Plusieurs reportages dans la presse écrite, plusieurs séquences télévisées ont mis à l'honneur et sous les feux de l'actualité, ces femmes extraordinaires, ces premières femmes pilotes militaires françaises, ce qui d'ailleurs était historiquement faux. Cela a engrendré de façon bien compréhensible des jalousies d'autant plus fortes que les pilotes masculins étaient, dans le même temps, soumis à de dures conditions de travail. Les femmes ne comprenaient pas car elles n'avaient pas demandé de telles "faveurs" si l'on peut s'exprimer ainsi. Le commandement a rapidement mis fin à cette situation qui, hélàs, a durablement marqué les esprits.

Que penser maintenant du manque supposé de motivation et de disponibilité ? L'attrait pour un tel métier nécessite au départ une réelle motivation aéronautique et/ou militaire. Elle est essentielle pour passer avec succès les différentes étapes de la sélection et de la formation. Ceci dit, la motivation peut être sujette à fluctuations. Une mauvaise insertion dans le milieu, un sentiment d'absence de perspectives de carrière attrayantes, un investissement parental important peuvent l'entamer de façon substantielle et les pilotes féminins apparaissent particulièrement exposées à ces égards.

Pour ce qui concerne l'absentéisme, nous constatons que les exemptions de vol ne sont pas plus longues ni plus nombreuses que chez les pilotes masculins. En fait, l'absentéisme reproché est celui lié à la grossesse. Une exemption de vol d'une année est en effet difficile à gérer quand elle n'est pas planifiée. C'est l'épée de Damoclès pouvant frapper à tout moment tel ou tel escadron qui a déjà du mal à assumer toutes ses missions à effectifs complets. A l'issue du congé de maternité, la reprise des vols nécessite un stage de requalification d'autant plus long et coûteux que la formation initialement acquise est plus spécialisée.

Lorsque l'enfant est là, l'investissement parental peut concurrencer l'investissement professionel. On le savait déjà pour la paternité qui était également un facteur de fragilisation du pilote et même un facteur humain de risque d'accident à prendre en compte. Les liens spécifiquement plus forts entre la mère et son enfant font que la maternité mérite une attention particulière à ces égards. D'autant qu'il semble que la puissance de l'investissement maternel ne puisse pas être évalué à sa juste valeur par la femme avant d'avoir vécu la maternité. Sur les deux cas de baisse de motivation aéronautique après grossesse que nous avons observés, un cas a été transitoire mais un autre apparaît plus critique et durable. Il concerne un pilote moniteur qui après sa deuxième maternité estime que sa tâche nécessite un don de sa personne trop important et une attention de tous les instants dont elle ne se sent plus capable. Ce sont les faits mis en avant par l'intéressée même si par ailleurs il apparaît également que l'affectation récente n'était pas souhaitée.

Elever son enfant entraîne également parfois une moindre disponibilité en particulier lors de déclenchement de missions inoppinées ou lors de manoeuvres d'une certaine durée. Il convient de dire à ce propos que l'on commence à voir apparaître ce phénomène chez les pères de famille dont l'épouse a une profession également très contraignante ou les pères divorcés avec enfants à charge. Il s'agit d'un problème d'organisation mais aussi de manque de moyens sociaux adaptés. La société laisse toujours en général à la mère le soin de le résoudre tant bien que mal au détriment de sa réussite professionnelle. L'incompatibilité supposée entre les servitudes de la vie militaire et celles de la vie de mère de famille transparaissait jusque dans certains textes juridiques. En cas de mariage ou de grossesse, le pilote féminin servant sous statut d'officier de réserve en situation d'activité pouvait résilier, de plein droit son contrat. Cette disposition a été utilisée par un pilote militaire qui poursuit actuellement une carrière civile. Jugée discriminatoire, cette mesure a été abrogée fin 1989.

La question de la grossesse et de la charge de mère de famille apparaît bien comme l'obstacle principal à l'intégration harmonieuse des femmes en général et des pilotes féminins en particulier au sein de l'institution militaire ainsi qu'à l'extension de la féminisation des armées. Il s'agit d'un handicap professionnel incontestable bien que parfois grossi de façon délibérée et sans véritable souci de recherche de solutions. Néanmoins la plupart des femmes, à force de volonté, d'énergie et de motivation, le surmontent de façon satisfaisante.

5. CONCLUSION

La dynamique égalitaire a fait s'ouvrir progressivement les emplois du personnel navigant militaire aux femmes. Nous avons étudié la sélection, la formation et les emplois opérationnels des pilotes féminins de l'AA et de l'ALAT depuis l'origine de l'expérience, c'est-à-dire 8 années. Nous manquons de recul pour faire un bilan. Les effectifs observés sont modestes ; les femmes pilotes sont jeunes, la plupart encore célibataires, beaucoup n'ont pas encore gravi tous les échelons de la qualification professionnelle et de la hiérarchie militaire. Pourtant la tendance que nous indique notre travail est plutôt favorable. Les difficultés d'intégration, parfois aiguës aux débuts de la féminisation, se sont aplanies. Les collègues masculins et la hiérarchie ont appris à travailler en meilleure intelligence avec les personnels féminins. Ce n'est qu'un début et bien des difficultés persistent car il s'agit d'une vraie révolution sociologique nécessitant une profonde modification des concepts et des comportements. Les progrès ont été possibles et se poursuivent car les pilotes féminins, dans l'ensemble, ont montré leurs capacités, techniquement, physiquement et psychologiquement parlant, à tenir les emplois proposés.

Des problèmes subsistent, en particulier ceux liés à la maternité, et à la vie de mère de famille. Ils réclament des solutions : adaptation des statuts, création de structures sociales par exemple. La réflexion sur les techniques et sur les normes de sélection doit être permanente avec pour but de choisir les éléments les meilleurs en fonction des aptitudes qu'ils démontrent et non de leur sexe. Or des insuffisances sont visibles actuellement pour certains emplois : absence de test de force physique spécifiquement aéronautique, absence d'élément d'appréciation de l'aptitude psychologique au maniement de la force armée, c'est-à-dire de tuer au service de la nation.

Au total, on peut être raisonnablement optimiste quant à la poursuite de la féminisation des emplois de pilotes militaires. Elle restera pragmatique, avec le double souci constant de "garantir à la femme, dans tous les domaines, des droits égaux à ceux de l'homme"* (* préambule de la Constitution de la République Française de 1946) et de préserver la mailleure efficacité opérationnelle possible à nos armées.

A N N E X E

LES TEXTES JURIDIQUES

(1) Décrets du 22.12.1975

75 1208 portant statut particulier du corps des officiers de l'Air, officiers mécaniciens de l'Air et officiers des bases de l'Air
75 1213 portant statut particulier des sous-officiers de carrière de l'Armée de l'Air
75 1206 portant statut particulier du corps des officiers des armes de l'Armée de Terre
75 1211 portant statut particulier des corps de sous-officiers de carrière de l'Armée de Terre.

(2) Note n° 20141 du 20.10.1981

(3) Décrets du 10.03.1983, n° 83 187 et 83 184

(4) Instruction 15000 du 21 janvier 1980 et 15001 du 16 mars 1983 relatives au recrutement d'élèves pilotes de l'Armée de l'Air à vocation d'officiers de réserve en situation d'activité (masculin et féminin) refondues dans l'instruction unique 15000/DPMAA/4/INST du 8 juillet 1986.

(5) Arrêtés du 31 mars 1985 fixant les emplois susceptibles d'être tenus par les officiers féminins (sous-officiers féminins de carrière) dans les armes de l'Armée de Terre. BOC/PP du 8 juillet 1985, n° 28.

REVUE DES CANDIDATURES FEMININES A LA FONCTION DE PILOTE A L'ARMEE BELGE

par le

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et le

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RESUME

L'auteur passe en revue les candidatures féminines aux fonctions de pilote à l'Armée Belge. Parmi septante-trois candidates examinées du 01 Jan 83 au 31 Jul 89 au Centre de Médecine Aérospatiale, cinq furent trouvées aptes au pilotage mais aucune candidate n'a pu entamer l'instruction de pilote.

Les causes d'élimination sont étudiées et classées par ordre de fréquence dans la population globale, selon l'ordre de passage des épreuves et selon la catégorie de recrutement. Une comparaison est effectuée avec les sujets masculins.

Les causes les plus fréquentes du rejet des candidates sont : l'insuffisance du score de psychomotricité, la myopie et l'insuffisance de longueur des jambes.

REVIEW OF FEMALE APPLICANT AIR-CREW IN THE BELGIAN FORCES

by Med Col VANCUTSEM C., CO of C Med Aerospace BAF and
Med Col VANDENBOSCH P., Director Aeromedical Services BAF.

ABSTRACT

The female applicant pilots in the Belgian Armed Forces have been evaluated. In the period from JAN 83 to JUL 89, seventy three female applicants were examined in our Centre of Aerospace Medecine. Only five of them have been declared physically fit as pilot, but no one could start the instruction.

The physical reasons of rejection are studied according to the frequency in the total population, and ranked in accordance with the different criteria and the category of recruitment.

A comparison is made between male and female applicants. The most frequent causes of rejection are : insufficient psychomotoric score, myopia and too short legs.

REVUE DES CANDIDATURES FEMININES A LA FONCTION DE PILOTE A l'ARMEE BELGE

par le Med Col VANCUTSEM C., Comd du C Med Aerospace et le Med Col VANDENBOSCH P., Directeur du Service Médical de la Force Aérienne.

Le Centre de Médecine Aérospatiale de la Force Aérienne Belge compte parmi ses missions la sélection des candidats pilotes de chasse pour la Force Aérienne et des candidats pilote d'aviation légère (hélicoptères et avions légers) des Forces Terrestre et Navale.
(N.B. : candidat élève-pilote = CEP).

Du 1er janvier 1983 au 31 juillet 1989, soit en six ans et demi, 73 candidates féminines au pilotage ont été examinées dans notre centre (C Med Aerospace). A ce jour, cinq candidates ont été trouvées aptes mais aucune n'a pu entamer l'instruction de pilote.

Nous allons en analyser les motifs et nous diviserons cette revue en cinq parties :

a. CEP medicopsychologiquement aptes mais NON engagées.

b. Causes médicales d'élimination par ordre de fréquence.

c. Causes médicales d'élimination par ordre de passage des épreuves.

d. Classification par catégorie et recrutement. (ERM, SERDI, Lt Avn)*

e. Comparaison avec les sujets masculins.

1. CEP MEDICOPSYCHOLOGIQUEMENT APTES MAIS NON ENGAGEES.

   a. 73 CEP ont été examinées (N = 73).

   b. 5 ont été trouvées aptes au pilotage à l'issue des phases I et II de la sélection soit 6,85 %.

   c. Aucune CEP n'a pu entamer l'instruction comme pilote pour les motifs suivants :

      - Soit échec aux épreuves sportives d'entrée à l'ERM,
      - Soit échec à l'examen d'entrée à l'ERM,
      - Soit non classées en ordre utile au concours d'entrée.

2. CAUSES MEDICOPSYCHOLOGIQUES D'ELIMINATION PAR ORDRE DE FREQUENCE.

   Les pourcentages sont calculés sur l'ensemble des candidates (N = 73).

   a. Causes neuropsychiques : 27 soit 36,9 %.

      Elles se subdivisent en :

      (1) pathologie psychique franche + EEG inhibé : 1 soit 1,36 %

      (2) cause neurologique (EEG irritatif) : 1 soit 1,36 %

      (3) score de psychomotricité insuffisant : 25 soit 34,24 %

      Le déficit en fait de psychomotricité est la cause principale du rejet des candidates féminines (plus d'un tiers).

   b. Causes ophtalmologiques : 23 soit 31,50 %.

      Elles se subdivisent en :

      (1) déficit d'acuité visuelle pur : 2 soit 2,72 %

      (2) myopie : 20 soit 27,39 %

      (3) troubles de la fixation binoculaire : 1 soit 1,36 %

      La myopie représente donc la deuxième cause d'inaptitude des candidates.

   c. Biométrie : 14 (26) soit 19,17 % (35,61 %)

      L'insuffisance de longueur de jambes représente également une cause fréquente d'élimination : 14 CEP soit 19,17 %.
      De plus chez 12 autres CEP soit 16,43 % cette cause est associée à une autre soit ophtalmologique soit score de psychomotricité insuffisant. Néanmoins, cette insuffisance de longueur de jambes est éliminatoire et se présente donc chez 26 CEP sur 73 soit 35,61 %.

   d. Causes oto-rhino-laryngologiques : 1 soit 1,36 %.

      Il s'agit d'un barotraumatisme manifesté lors de l'épreuve au caisson hypobare.
      (N.B. : Les candidates ont deux chances pour cette épreuve).

3. CAUSES D'INAPTITUDE SELON L'ORDRE DE PASSAGE DES EPREUVES.

   La sélection suit un processus bien déterminé. Une première phase comprend successivement l'examen ophtalmologique, la biométrie, l'examen ORL et l'examen de la psychomotricité. Cette première phase offre le taux le plus élevé de rejet. Une deuxième phase comprend les épreuves sportives légales (sauf pour les candidates à l'Ecole Royale Militaire), l'examen médical approfondi, l'examen psychologique avec interview. Cette deuxième phase offre un taux de rejet nettement moindre.

* ERM : Ecole Royale Militaire.
SERDI : Service Recrutement de la Force Aérienne Belge (cadre auxiliaire).
Lt Avn : Aviation légère des Forces Terrestre et Navale.

REPARTITION DES CAUSES D'ELIMINATION

a. Phase I (1ère matinée) (N = 73).

(1) Causes ophtalmologiques :

- acuité visuelle : 2
- myopie : 20
- fixation binoculaire : 1

Total : 23 soit 31,50 %.

Dans 11 cas, la cause ophtalmologique était associée à une insuffisance de longueur de jambes.

(2) Biométrie :

- insuffisance de longueur de jambes : 14 soit 19,17 %
- idem associée à une autre cause : 12 soit 16,43 %

Soit 11 fois associée à une cause ophtalmologique et 1 fois associée à une cause psychomotrice.

(3) Test 506 : (épreuve collective de type papier-crayon utilisée en premier rang dans le testing psycho-moteur).

- 1 échec soit 1,36 %.

(4) Après la première matinée de sélection, 37 candidates sur 73 sont éliminées soit 50,68 %. Il reste 35 candidates sur 72 soit 47,94 % et ceci modifie considérablement les calculs ultérieurs si l'on considère que les éliminations se poursuivent sur une population restante de 35 candidates (N' = 35) au lieu de 73.

b. Phase I (N' = 35)

(1) Echec à l'épreuve du caisson : barotraumatisme répété : 1 soit 2,85 %

(2) Insuffisance de psychomotricité : 24 soit 68,57 %.
Dans un seul cas, ceci était associé à une insuffisance de longueur de jambes.

CONCLUSIONS

L'insuffisance de psychomotricité des candidates ne représente qu'un peu plus d'un tiers des causes d'échec si l'on considère l'ensemble des candidatures féminines mais représente un fait plus de deux tiers des causes d'échec des candidates si l'on considère la population à laquelle ce testing a été réellement appliqué.
A l'issue de la phase I, il reste 10 candidates (N'' = 10) sur un total de 73 (soit 13,69 % de la population totale ou 10 candidates sur 35) (soit 28,54 % si l'on ne compte que les candidates ayant traversé la première matinée de selection).
Les scores suivants sont minimes s'ils sont rapportés à la population totale (N = 73) mais deviennent très importants s'ils sont rapportés à la population restante de 10 candidates. Ils perdent à ce moment toute valeur statistique.

c. Phase II

Elle dépiste seulement :

- 1 cause neurologique : soit 1,36 % (N = 73)
  2,85 % (N' = 35)
  10,00 % (N" = 10)

- 1 cause psychiatrique : soit 1,36 % (N = 73)
  2,85 % (N' = 35)
  10,00 % (N" = 10)

D'autres candidates sont soit absentes, soit se désistent, soit échouent aux examens d'entrée à l'Ecole Royale Militaire :

- 2 soit 2,73 % (N = 73)
  5,71 % (N' = 35)
  20,00 % (N" = 10)

Total des rejets en phase II : 4

Une candidate est encore en cours d'examen.

Il reste donc 5 candidates médicopsychologiquement aptes.

CONCLUSIONS

L'insuffisance du score de psychomotricité, la myopie et l'insuffisance de longueur de jambes sont donc les trois causes principales d'élimination des candidates féminines.

4. CLASSIFICATION PAR CATEGORIE DE RECRUTEMENT

Le recrutement des pilotes se fait dans différentes catégories de population.

a. Les candidat(e)s présentant l'examen d'entrée à l'Ecole Royale Militaire (candidats officiers de carrière).

b. Les candidat(e)s pilotes recrutés directement dans le milieu civil à l'issue des études secondaires (CEP SERDI, cadre du Personnel Navigant auxiliaire : carrière de 12 ans maximum).

c. Les candidat(e)s pilotes de l'Aviation légère recrutés dans le milieu militaire (candidats officiers et Sous officiers de carrière dans le personnel navigant des Forces Terrestre et Navale).

La comparaison des trois catégories ne montre pas de différences très importantes dans le pourcentage d'aptitude (environ 25 %) : voir tableaux (chiffres des années 1985 à 1988 sur l'ensemble des candidats masculins et féminins).

5. COMPARAISON AVEC LES SUJETS MASCULINS

Ces tableaux nous permettent simultanément de comparer les pourcentages d'aptitude des candidats et candidates.

CLASSIFICATION BY CATEGORY OF RECRUITMENT

COMPARISON WITH MALE APPLICANTS

		1983 FEMALE ONLY	1984 FEMALE ONLY
CEP/ERM	N	4	3
	UNFIT	4	3
	FIT	0	0
	ABSENT	0	0
CEP/SERDI	N	0	0
	UNFIT	0	0
	FIT	0	0
	ABSENT	0	0
CEP/Lt Avn	N	2	4
	UNFIT	2	3
	FIT	0	1 the first !
	ABSENT	0	0

		1985		1986		1987		1988	
		M	F	M	F	M	F	M	F
CEP/ERM	N	309	7	265	2	199	4	261	7
	UNFIT	258 (83.5 %)	7 (100 %)	164 (61.8 %)	2 (100 %)	123 (61.8 %)	4 (100 %)	186 (71.2 %)	6 (86 %)
	FIT	47 (15.2 %)	0	84 (31.6 %)	0	62 (31.1 %)	0	75 (28.7 %)	1 (14 %)
	ABSENT	40	0	4	0	14	0	81	0
CEP/SERDI	N	390	0	393	0	577	0	442	11
	UNFIT	255 (66.4 %)	0	236 (60.0 %)	6 (100 %)	309 (53.5 %)	0	288 (65.75%)	11 (100 %)
	FIT	55 (14.1 %)	0	190 (22.9 %)	0	187 (32.4 %)	0	154 (34.8 %)	0
	ABSENT	82	0	2	0	74	0	169	0
CEP/Lt Avn	N	182	2	260	3	84	2	250	11
	UNFIT	146 (80.2 %)	2 100 %)	154 (59.2 %)	3 (100 %)	38 (45.2 %)	1 (50 %)	181 (72.9 %)	9 (81 %)
	FIT	29 (15.9 %)	0	65 (25 %)	0	36 (42.8 %)	1 (50 %)	56 (22.9 %)	2 (1.9 %)
	ABSENT	9	0	5	0	1	0	24	0

		TOTAL FROM 1985 TO 1989		1989	
		M	F	M	F
CEP/ERM	N	1034	20		0
	UNFIT	731 (70.69 %)	19		0
	FIT	268 (25.91 %)	1 (5 %)		0
	ABSENT	139	0		0
CEP/SERDI	N	1802	11		9
	UNFIT	1088 (60.37 %)	11		7
	FIT	486 (26.97 %)	0		0
	ABSENT	327	0		2
CEP/Lt Avn	N	775	18		2
	UNFIT	519 (66.96 %)	15		1
	FIT	186 (24 %)	3 (16.6 %)		0
	ABSENT	39	0		0 (1 in course)

CONCLUSIONS

Ces chiffres montrent que les chances de succès des candidates féminines sont nettement moindres que celles des sujets masculins, surtout pour les candidates recrutées dans le milieu civil en vue d'une carrière de pilote auxiliaire.
Les chances d'accès à une carrière de pilote s'améliorent cependant lorsque les candidates sont déjà militaires (recrutement pour l'aviation légère) ou candidates à l'Ecole Royale Militaire (formation de niveau officier).
Ces conclusions confirment l'opinion générale selon laquelle seules les femmes exceptionnelles seront aptes à une carrière de pilote.

PRISE EN COMPTE DES ASPECTS MORPHOLOGIQUES DES PERSONNELS FEMININS DES ARMEES

APPLICATION A LA CONCEPTION D'UN COUVRE-FACE

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RESUME -

La dotation des armées en équipements de protection faciale Nucléaire, Biologique et Chimique (N.B.C.) ne concernait jusqu'à présent que les personnels masculins. Les contraintes d'utilisation militaires actuelles imposent une nouvelle approche conduisant à la conception d'équipements capables de satisfaire pour les hommes et pour les femmes, aux critères suivants :
- étanchéité,
- confort lors d'un port de longue durée,
- maintien d'une efficacité opérationnelle présentant un minimum de dégradation.

Pour répondre aux besoins qu'impose la conception d'un couvre-face, il importe de définir le nombre minimum de tailles capables d'équiper et de protéger dans des conditions optimales un maximum d'utilisateurs. Parmi les éléments intervenant dans le confort et l'étanchéité, il est certain qu'une bonne adéquation entre le bourrelet du couvre-face et la partie correspondante du visage servant d'appui demeure essentielle. Pour aboutir à ce compromis, plusieurs études ont été menées sur la morphologie des visages des utilisateurs concernés.

INTRODUCTION -

Les armées modernes incorporent en leur sein un effectif non négligeable de personnel féminin. L'armée française en 1988, à l'exclusion des personnels civils travaillant pour elle, comptait dans ses rangs 86,1% d'hommes et 13,9% de femmes. Ainsi, sur un effectif de personnel d'active et d'appelés de 553.695 personnes, 76.963 étaient des femmes. La participation de cette partie de la population aux activités opérationnelles et les nécessités de protection inhérentes aux dangers d'une guerre moderne impliquent que l'utilisation d'équipements concerne de plus en plus les personnels féminins.

Aussi, la conception des équipements ne peut plus être réalisée uniquement à partir des caractéristiques anthropométriques de la population masculine (1, 2). Les équipements doivent être conçus en tenant compte des variations existant à l'intérieur d'une nouvelle population incluant désormais des personnels féminins et masculins.

Le développement du couvre-face de protection N.B.C. pour les personnels militaires fournit à cet égard une approche exemplaire illustrant les propos précédents.

Pour parvenir au but recherché, l'étude s'est déroulée selon les phases suivantes :
- définition et description morphologique des populations concernées : enquêtes anthropométrique et biostereométrique,
- définition de système de tailles,
- détermination par Conception Assistée par Ordinateur (CAO) des couvre-faces et élaboration des procedures de Fabrication Assistée par Ordinateur (FAO),
- réalisation et validation des tailles retenues.

METHODE -

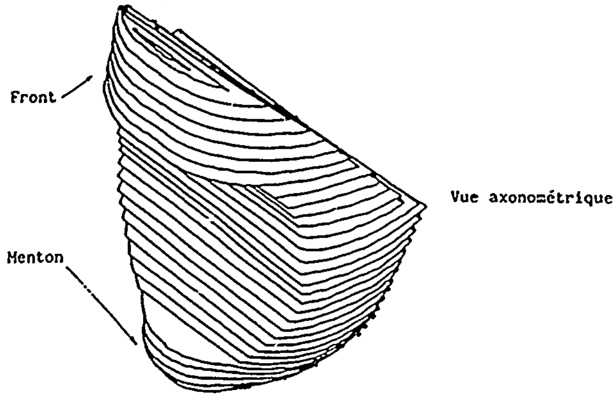
L'application du protocole expérimental a fait l'objet de plusieurs études.

La première d'entre elles (3) a consisté à déterminer les profils morphologiques typiques les plus caractéristiques de la population utilisatrice de référence. Ceci a été réalisé au moyen :
- de données existant dans la Banque de données d'anthropométrie de ERGODATA ;
- d'une enquête anthropométrique effectuée sur des échantillons de personnels militaires féminins et masculins. Cette enquête menée sur le terrain avait pour double objectif : la mise à jour des données ainsi que la selection, parmi les sujets mesurés, d'un échantillon d'hommes et de femmes représentatifs des typologies faciales de la population étudiée. Cette enquête anthropométrique a été effectuée dans les trois armées et a porté sur un échantillon global de 208 hommes et 300 femmes ;
- d'une étude biostéréométrique de 60 sujets, 30 hommes et 30 femmes extraits des échantillons précedents. Sur ce groupe expérimental, présentant des morphologies très diversifiées, a été effectue un relevé tridimensionnel d'enveloppes faciales et de points anatomiques de référence (4,5). Cette démarche a permis de caractériser les typologies les plus marquées des enveloppes faciales, ainsi que les amplitudes de variations propres a chaque typologie. Les informations recueillies au cours de cette phase expérimentale ont été utilisées pour déterminer la géométrie du bourrelet d'une maquette de couvre-face. Cette maquette de couvre-face a été conçue et fabriquée par CAO-FAO (figure n°1).

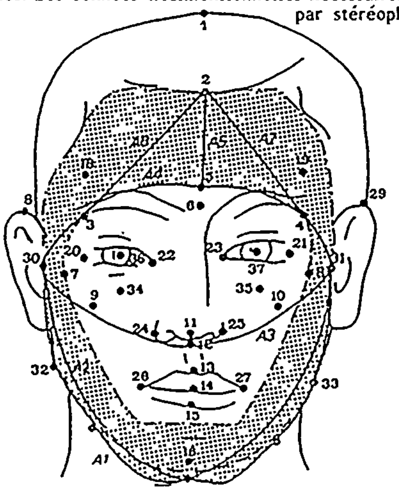
La deuxième étude (6) a consisté à vérifier la qualité de l'adaptation fonctionnelle de la maquette du nouveau masque de protection sur un échantillon de la population militaire de l'Armée de l'Air. Les expérimentations ont également porté sur un échantillon d'hommes et de femmes, de morphologie différente, de manière à vérifier la validité des formes retenues pour le bourrelet ainsi que les possibilités de recouvrement de tailles. Pendant cette phase expérimentale, la durée du port de couvre-face a été fixée à 6 heures avec deux périodes de recueil de données physiologiques, de tests, de questionnaires de vécu de situation en début et en fin d'expérimentation, avec un suivi continuel des sujets tout au long de l'essai. Les informations recueillies ont permis de mettre en évidence les imperfections qu'il fallait corriger et aussi de valider le choix sur la forme du bourrelet et le concept général du couvre-face.

La troisième étude (7) a eu pour but de valider expérimentalement sur un autre échantillon de la population militaire de l'Armée de l'Air, la bonne adaptation fonctionnelle sur le plan étanchéité et confort des quatre tailles

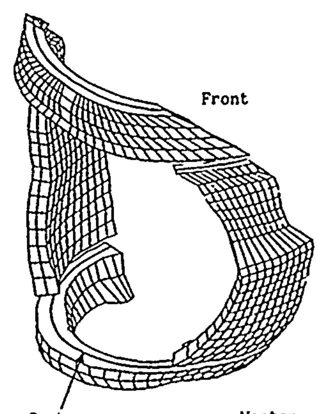
de couvre-face retenues. Elle a permis également de tester la validité d'une méthode d'attribution de la taille de masque en fonction de deux mesures anthropométriques.



Contours du visage utilisé pour l'étude par CAO de la géométrie des zones d'appui prévisibles du bourrelet du couvre-face. Les données tridimensionnelles nécessaires à la définition des contours des visages ont été obtenues par stéréophotogrammétrie.



Points anatomiques
et zones traitées en CAO.



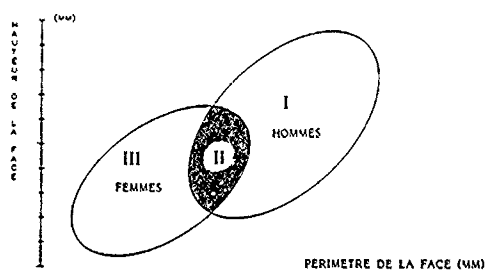
Représentation d'un coutour typique : détermination de la géométrie du contour moyen et de la variabilité interindividuelle pour un groupe donne.

Figure n° 1
Typologie du visage - Application à la conception du nouveau masque des armées (NMA).

RESULTATS -

Variabilité générale observée -

L'exploitation des résultats des mesures (tableau n° 1) montre qu'entre la population masculine et feminine il existe des variations d'amplitude pour chaque donnée anthropométrique. D'une façon générale :
- les amplitudes maximales appartiennent en grande partie à la population masculine (I),
- une large portion des deux populations présente une amplitude commune (II),
- les amplitudes minimales sont principalement le fait de la population féminine (III).



Paramètres statistiques	FEMMES				HOMMES			
Mesures exprimées en mm.	m	σ	mini	maxi	m	σ	mini	maxi
1 - Poids (en Kg)	58,8	10,2	44	108	72,9	10,0	50	123
2 - Stature	[illegible]	68,7	1468	1834	1750,0	61,3	1604	1940
3 - Ht.crinion-gnathion	[illegible]	8,1	153	188	185,7	9,9	143	215
4 - Ht.glabelle-gnathion	126,8	5,5	116	141	136,7	6,8	119	161
5 - Largeur bifronto-temporale externe	[illegible]	4,6	95	115	109,0	5,8	96	124
6 - Largeur suture fronto-malaire	115,5	5,6	106	143	121,6	4,9	108	140
7 Largeur bitragus	135,0	3,9	127	149	144,4	5,5	128	160
8 - Largeur bizygomatique	134,2	3,8	123	143	143,1	5,6	129	159
9 - Largeur bigoniale	[illegible]	4,9	95	117	111,6	6,9	94	140
10 - Tragus pronasal direct	[illegible]	5,0	121	144	140,9	5,3	127	151
11 - Hauteur de la face	[illegible]	5,2	103	128	123,1	5,9	107	143
12 - Hauteur du nez	[illegible]	3,3	42	58	55,5	3,9	46	65
13 - Largeur maxi. du nez	[illegible]	2,2	28	38	36,5	2,7	31	48
14 - Saillie médiane du nez	[illegible]	1,9	18	27	23,7	2,3	15	32
15 - Larg. bi-ectocanthion	93,4	3,7	87	100	98,6	4,3		110
16 - Larg. bi-endocanthion	22,7	1,9	19	28	23,7	2,1	18	30
17 - Arc bitragus-frontal	289,9	12,9	267	314	306,5	12,9	273	340
18 - Arc bitragus pronasal	295,8	12,7	269	322	313,7	13,1	283	342
19 - Arc bitragus gnathion	306,6	13,3	263	337	333,9	14,9	285	375
20 - Périmètre de la tête	550,3	16,1	518	592	575,0	16,6	529	625

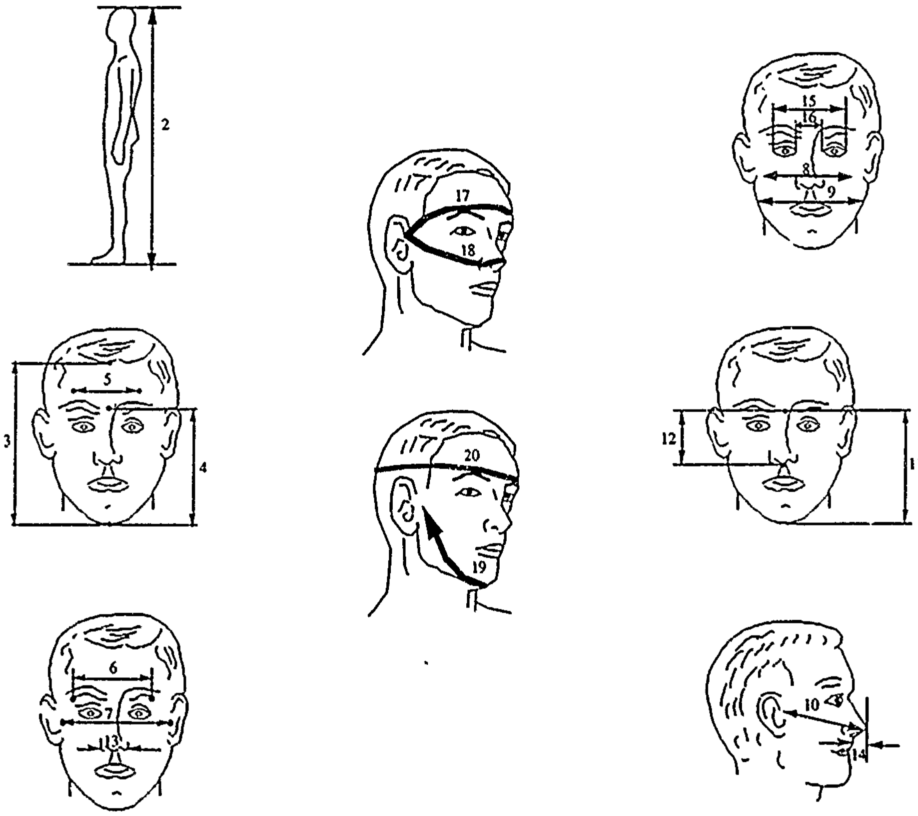


Tableau n° 1
Comparaison des principales mesures du visage et de la tête entre un échantillon féminin et un échantillon masculin de l'Armée de l'Air Française.

La variabilité générale observée étend donc à la fois ses limites vers les fortes et les faibles valeurs. Il s'agit en fait d'une nouvelle population au sens statistique du terme. Cette réalité anthropométrique se traduira par le fait que parmi les personnels équipés d'une grande taille de couvre-face, nous trouverons beaucoup plus d'hommes que de femmes. La taille moyenne satisfera en quantité quasiment égale les deux composantes de la population militaire ; alors qu'une petite taille sera à même d'équiper plus de femmes que d'hommes.

Définition du nombre de tailles -

Il convient d'abandonner la dichotomie anthropométrique traditionnelle Homme-Femme, pour résoudre le problème de la connaissance des formats différents de visages existant à l'intérieur de cette population globale. C'est ce qui a été réalisé grâce à l'étude biostéréométrique, qui a permis d'aboutir à une description de la variabilité interindividuelle des formes d'enveloppes faciales, permettant de définir sur un profil morphologique 5 typologies de visages (figure n°2). Comme dans chaque typologie mise en évidence, on retrouve dans des proportions variables des hommes et des femmes, on peut considérer qu'il n'existe donc pas de typologie morphologique spécifique aux personnels féminins ou masculins.

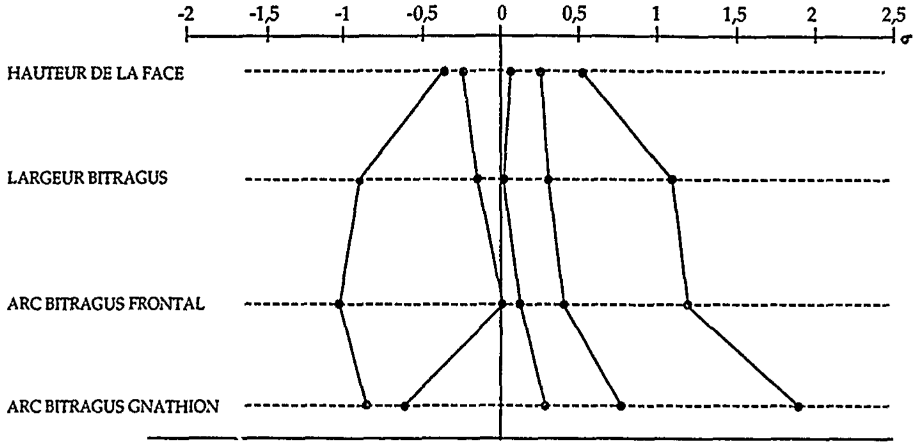


Figure n° 2
Comparaison des principales caractéristiques moyennes de 5 groupes par rapport aux valeurs moyennes de l'échantillon de référence.

Par ailleurs, plus les variations d'amplitudes anthropométriques relevées au sein d'une population sont élevées, plus grand sera le nombre de tailles d'équipement nécessaires au recouvrement maximal des éléments composant cette population. En l'occurence, 5 tailles de couvre-face représentent le nombre optimal pour satisfaire au plus grand recouvrement de la population concernée. Toutefois, sachant que lorsqu'on arrive dans les valeurs extrêmes de la distribution gaussienne d'une population, il y a toujours un pourcentage de sujets qui, sortant des limites, ne peuvent être équipés de façon correcte, il est habituel sur le plan de la conception et de la fabrication d'équipement de chercher à satisfaire la tranche 5 - 95% de la population concernée. C'est le compromis qui a été retenu pour la fabrication des couvre-faces. C'est pourquoi un regroupement des typologies correspondant aux visages les plus petits a conduit à ne retenir ultérieurement que quatre tailles de masques (tableau n°2, figure n°3).

Groupes	Hauteur glabelle-gnathion (mm)	Périmètre de la face (mm)
1	120 - 132 12	540 - 625 85
2	132 - 145 13	540 - 600 60
3	130 - 143 13	600 - 660 60
4	143 - 155	590 - 675

Tableau n° 2
Proposition de définition des 4 tailles de couvre-faces à partir des mesures fonctionnelles directement en rapport avec les zones d'appui du bourrelet.

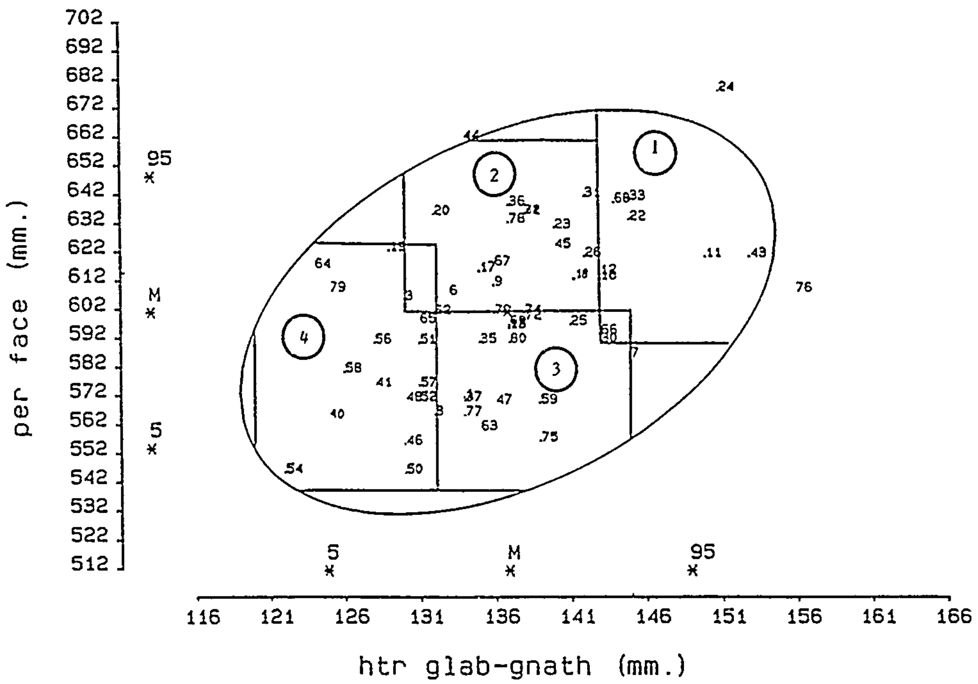


Figure n° 3
Proposition de définition des tailles en fonction de mesures fonctionnelles : hauteur glabelle-gnathion et périmètre de la face.

Validation de l'adaptation morphologique -

L'attribution d'une des 4 tailles de couvre-faces était déterminée par la relation de deux mesures anthropométriques (figure n°4) :
- le périmètre de la face correspondant à la somme des arcs bitragus frontal et bitragus gnathion,
- et la hauteur glabelle-gnathion.

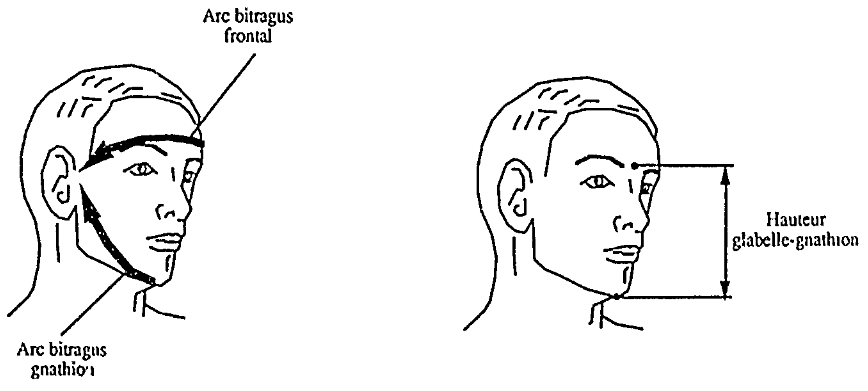


Figure n° 4
Mesures servant à déterminer en première approche la taille du masque.

La projection des valeurs respectives du périmètre de la face et de la hauteur glabelle-gnathion sur le graphique (figure n°5) détermine par leur point d'intersection l'attribution de la taille du masque pour le sujet considéré.

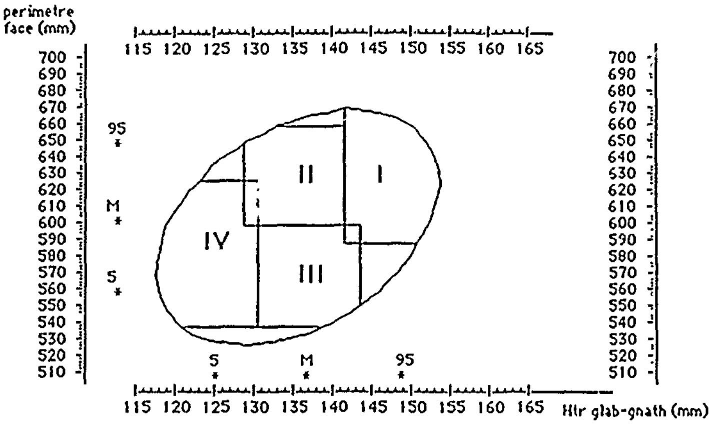


Figure n° 5
Graphique servant à déterminer, par projection des valeurs anthropométriques du sujet, la taille du masque susceptible de correspondre à sa morphologie.

Pour le cas des sujets se situant à la frange de deux, voire de trois tailles, seul l'essai des diverses tailles peut apporter une réponse, au moins en ce qui concerne le confort.

Une fois la mise en place et les réglages du masque réalisés sous contrôle, la vérification de l'adequation visage-masque était effectuée à l'aide du test d'étanchéité. Cette phase expérimentale représentait le moment de vérité. La première réponse fournie permettait de savoir si la taille affectée selon les critères morphologiques présentait ou non les facteurs de protection requis. Dans le cas d'un résultat négatif, la deuxième reponse à trouver consistait à savoir s'il existait ou non une autre taille de masque susceptible de protéger efficacement le sujet.

En ce qui concerne la méthode d'affectation des tailles de masques à partir de la relation entre deux criteres anthropométriques du visage, les résultats montrent qu'elle s'est avérée fiable dans 95% des cas où la première affectation s'avérait bonne pour la morphologie et le confort. Par contre, le test d'étanchéité, critère primordial d'affectation, impose une redistribution qui conduit dans 32% des cas à la réaffectation d'une autre taille.

On peut déduire de ce résultat qu'il n'existe pas de méthode simple d'affectation fondée sur la seule relation entre 2 ou 3 mesures anthropométriques susceptibles de permettre d'attribuer à un sujet de façon tout à fait fiable une taille de masque. Cela provient des particularités du visage caractérisé par l'absence de fortes corrélations entre les diverses mesures auxquelles doit être associé le facteur morphologique lié à l'existence d'une dissymetrie faciale (8, 9). C'est pourquoi, la méthode proposée peut être utilisée comme une première approche dans la détermination d'une taille et d'un confort, mais l'attribution définitive doit toujours être confirmee par un test d'étanchéité, vérification indirecte de l'adéquation des deux formes : visage et bourrelet.
En ce qui concerne la validation des tailles de masque en tant que protection, nous constatons que 95% de la population globale se trouvent protégés par l'une des 4 tailles de masque existant.

Par contre, si l'on étudie séparément les échantillons d'hommes et de femmes composant la population globale, on constate que :
- si l'on admet le port de barbe comme se révélant incompatible avec le port du masque, ce qui a été démontré au cours de l'expérimentation, on remarque que la protection de la population masculine est assuree à 100% ;
- en revanche, si 80% de la population féminine peut être equipée d'une taille de masque la protegeant efficacement, 20% de femmes ne trouvent pas une protection suffisante.

Ce manque de protection pour les personnels féminins provient essentiellement :
- de l'implantation des cheveux dans la partie fronto-temporale qui coïncide avec l'appui du bourrelet ;
- des régions maxillaires caractérisées par de très petites dimensions ;
- des visages émaciés ayant une morphologie en "lame de couteau".

L'étude stéréométrique menée à ce propos a confirmé que les problemes d'etancheite du masque sont lies a une certaine typologie du visage caractérisée par la convergence simultanée de trois facteurs anatomiques (figure n°6):
- une dimension relativement grande de l'angle d'ouverture de la face ;
- une hauteur glabelle-gnathion relativement petite ;
- un menton à tendance rétrognatne, c'est-à-dire en recul relatif par rapport au plan de la face.

La présence de ces trois critères caractérise les visages petits pour lesquels toutes les valeurs des dimensions anthropométriques sont faibles, y compris celle de la profondeur de la face.

Si ces observations sont plus fréquemment mises en évidence sur la population féminine, on sait qu'il existe également des visages masculins, notamment ceux de jeunes appelés qui, au sortir de l'adolescence, presentent ce type de morphologie.

Que peut-on envisager pour cette catégorie de personnes qui représentent environ 5% de la population militaire française globale ?

La suggestion consiste soit à parfaire l'adaptation de la petite taille du masque, notamment en procédant à une modification du bourrelet d'appui ou bien en créant une cinquième taille de masque susceptible de protéger les personnels militaires masculins et féminins appartenant à cette frange de la population.

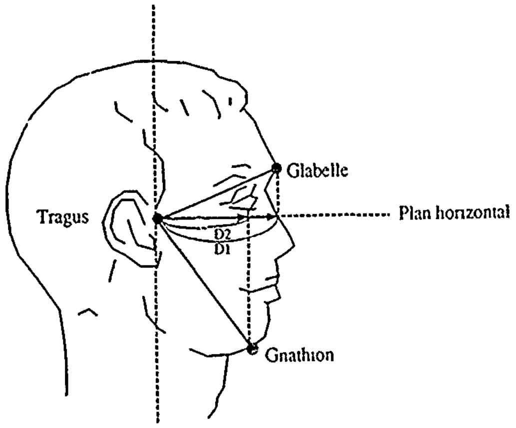


Figure n° 6
Projection sur un plan horizontal de référence des repères anatomiques glabelle et gnathion.

CONCLUSIONS -

La presence d'un personnel féminin au sein d'une population militaire crée, au sens statistique du terme, une nouvelle population dont la variabilité se trouve significativement accrue, avec une amplitude plus grande de la dispersion des données anthropométriques caracterisant cette population globale, hommes et femmes.

En dehors de l'exclusion de certains types morphologiques susceptibles de constituer de nouveaux critères selectifs, cette considération biologique implique, au niveau de la conception d'équipements individuels, qu'il faudra prevoir un nombre accru de tailles pour couvrir l'ensemble de la population. Cette nécessite se faisant d'autant plus impérative lorsqu'il s'agit d'équipement de protection.

Ainsi, l'incorporation d'un personnel féminin au sein de l'armee représente un fait qui n'est pas sans conséquence puisqu'il implique des choix liés soit au mode de recrutement, soit aux conséquences economiques relatives à l'accroissement du nombre de tailles des équipements individuels militaires.

Remerciements: Cette recherche a été effectuée avec le soutien de la DRET (Groupe 9) et de l'ETCA-CEB

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AIRCREW/COCKPIT COMPATIBILITY: A MULTIVARIATE PROBLEM SEEKING A MULTIVARIATE SOLUTION

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SUMMARY

Aircrew/cockpit compatibility depends on an interaction between the anthropometry of individual aircrew members and the geometry of the cockpit. Selection criteria in the past have attempted to deal with this interaction, but the model was too simple. This is a multi-variate problem which requires a multi-variate solution. Essentially the problem is one of charting the region of intersection between the anthropometric data domain and a set of rules or criteria which define 'operability'. The nature of this problem was demonstrated through computer simulated fitting trials of subjects in a number of cockpit-like geometries. The simulations clearly demonstrate that membership in a particular category of 'fit' depends on interactions between workspace and anthropometry which are geometry specific. Further, the simulations show that the establishment of analytical expressions to define class membership is complex and appears to require a non-linear approach. The consequences of these results are discussed in terms of establishing selection standards and determining design criteria for cockpits which are compatible with these standards. It is argued that cockpit design must be based on an extensive sampling of human characteristics in order that the full range of interactions, between various anthropometric dimensions and the workspace, is represented.

1. INTRODUCTION

It is assumed that the purpose of applying anthropometric selection criteria is to screen out those candidates whose physical characteristics would be incompatible with the workspaces they must occupy or with the tools and equipment they must use in performing their duties. Obviously, selection criteria must reflect the limitations of the workplace environment if this goal is to be achieved. The link between operator selection and workspace geometry is inseparable, selection criteria should reflect the characteristics of the work environment, and workspace design should reflect anthropometric selection criteria. In practice this is seldom the case. Anthropometric selection criteria are often established solely within the domain of the anthropometric data, with apparently little acknowledgement that 'compatibility' depends on the interaction between the anthropometric characteristics of individual subjects and workspace geometry. Generally, selection criteria are based on regions of acceptance, typically established independently on each anthropometric variable of interest. Ranges for workspace design are similarly based.

This paper examines the effects of interactions between individual anthropometry and workspace geometry with a view to establishing the consequences of these interactions in developing selection strategies and guidelines for design. The problem of defining physical compatibility in the workspace, is essentially one of charting the region of intersection between an anthropometric data space and a set of rules or criteria which define 'operability' in a workspace. The non-linear multi-variate nature of this problem is demonstrated through computer simulated fitting trials of subjects in a number of cockpit-like geometries. The simulations make use of a simple sagittal plane manikin to represent the human skeletal form.

2. THE NEED FOR A MULTIVARIATE DISTRIBUTED APPROACH

Recent articles and letters in the human factors literature [1-3] have raised the issue of anthropometry and workspace design. Kleeman's contribution [3] supports the contention that perhaps all is not well with some of the established methods for applying anthropometric data to design, however, his suggestion to extend the design range from the more usual *5th* and *95th* percentile values to the *1st* and *99th* values may be begging the question. Perhaps the problem lies less with which percentile limits are chosen, but more with the way in which anthropometric data are applied.

The problems which result from assuming that anthropometric dimensions are perfectly correlated, is well documented [4-6] and it is recommended that multi-variate techniques be used in an effort to overcome limitations inherent in uni-variate methods [7]. Yet most traditional methods for the application of anthropometric data are uni-variate, so far as their ability to handle correlations between anthropometric variables is concerned. Falling within this category is the most common procedure for design, that is, the use of percentile data [8] mapped into the workspace domain through graphical procedures [7], drawing board manikins [9] or their computer generated counterparts [10-12].

Although the fallacy of the *average man* is well recognized [8], it would seem that an equally fallacious concept, the *n-percentile person*, is firmly entrenched within traditional methods. In making this claim it is accepted that few manikins, for example, are made entirely from segments of the same percentile, that is, all *5th* or all *95th* percentile values. Rather the criticism of these widely used methods stems from their limited, often non-existent, ability to represent the range of individual differences in the user population for any other than the most simple of workspace geometries.

A notable exception to this approach can be found in the work of Bittner et al. [13,14]. They argue that if an anthropometric data base is conceptualized as an *n*-dimensional hyper-space, then a relatively small number of suitably chosen manikins could characterize the hyper-ellipsoid surface which encloses any given proportion of a user population. From a principle component analysis, the hyper-space was estimated to be approximately 4-dimensional Normal, giving rise to a 'CADRE' of 17 manikins. Although the 17-member CADRE is intended primarily for workspace design, it is possible that this approach could be adapted to the development of selection criteria. However, CADRE is founded on the belief that points on a hyper-surface which enclose a given proportion of the population data, will retain this property after transformation from the domain of the anthropometric data into the workspace domain. This may not be the case with certain workspace geometries. There exists the possibility that the requirement to manipulate the position of operators to satisfy various criteria such as vision and reach, will

cause points lying within the enclosing surface in the space of the anthropometric variables to be mapped into regions external to the transformed enclosing surface in the workspace domain. Such a hypothesized region is illustrated in Figure 1 (Region A).

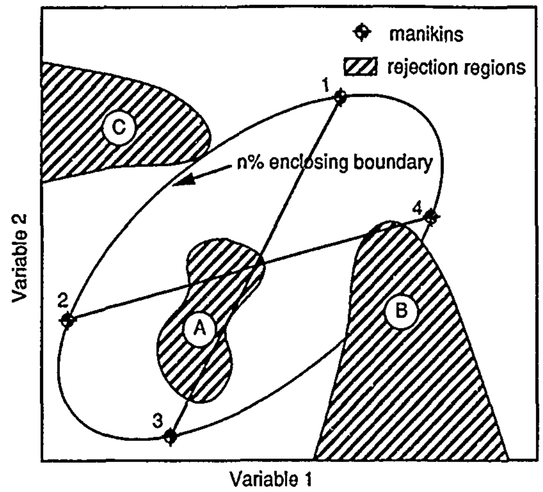

Figure 1. *Hypothesized rejection regions in anthropometric space.*

Even if closed regions of the type discussed above do not exist, there are other problems with CADRE. Sixteen manikins in CADRE are located on the hyper-ellipsoid enclosing surface, at the ends of an oblique axes system, which encloses 94% of the population data. The final manikin is located at the centroid. This provides for a sparse description of the enclosing surface, and a rejection region may not be sampled by the limited representation provided by CADRE (e.g. Region B in Figure 1). Although this problem could be addressed by a more detailed sampling of the enclosing surface, a final objection remains. Designing for a n-member CADRE constrains a rejection region to be tangent to the enclosing surface and never to cut it (e.g. Region C in Figure 1). Once the rejection region cuts the enclosing surface, the actual proportion of rejections can not be predicted by this n-member set. The net result is a conservative design, at least for those design areas not related to operator safety or critical performance. That is, actual rejection rates will generally be less than the 6% that might be expected from designing for manikins located on a 94% enclosing surface.

Therefore, in order to deal with the range of individual anthropometric differences and to know the rejection rates resulting from specific design or selection decisions, it is argued that not only is a multi variate approach required, but this approach must sample throughout the entire data space. Such distributed multi-variate representations have been used in a number of areas related to workspace design and assessment [13, 15, 16]. The power of these methods comes from their representation, to an accuracy determined by the level of sampling and the fidelity of the modelling process, of the full range of interactions between anthropometric dimensions and the workspace.

3. THE SIMULATION PROGRAM

The Simulated Anthropometric Fitting Trial (SAFT) software is a PASCAL program for PC or PC compatible computers, which simulates an anthropometric compatibility check of human subjects in a simple seated workstation geometry. The simulation is based on the five-link sagittal plane manikin [15] shown in Figure 2. Manikins are defined by five anthropometric variables. Link lengths are calculated by a monte-carlo process which, by a random sampling throughout the anthropometric data space, matches the means, standard deviations and correlation matrix of the 5-dimensional distribution from which the variables are drawn. All variables are constrained to lie within 3.5σ of their mean value. This arbitrary truncation avoids the occurrence of extreme outlyers. Workspace geometries are defined in terms of a vision line, a seat adjustment ramp, seat geometry, instrument panel location, floor line, and a range of heel points for pedal location and adjustment.

The simulation attempts to fit each member of a group of manikins (up to 1900) into a workspace according to a set of rules; for example, eye on or above the vision line, seat reference point on the seat ramp, and heel on the floor line within a given range. Manikins are divided into categories according to their 'fit' in the workspace. Fit is defined in terms of reach to panel and floor, heel within the range of adjustment, and trunk and knee angles within defined ranges.

The manikin's posture is determined by the seat parameters used for the simulation (i.e. the seat back and seat pan angles determine the eye link, trunk link and thigh link angles). When each manikin is fitted into the workspace, the fitting algorithm first places each eye point and seat reference point (SRP) on the vision line and seat ramp line respectively. From this position, reach to the panel is tested. If the panel is within the manikin's reach no further seat adjustment is made at this stage. If the panel is outside the manikin's reach, up to 5 degrees of seat rotation about the SRP is used in an attempt to improve the situation. No translation of the SRP is allowed. Seat rotation halts when the reach criterion is satisfied. Any manikin that fails to reach the panel under maximum seat rotation, is held in this final posture for the lower body assessments.

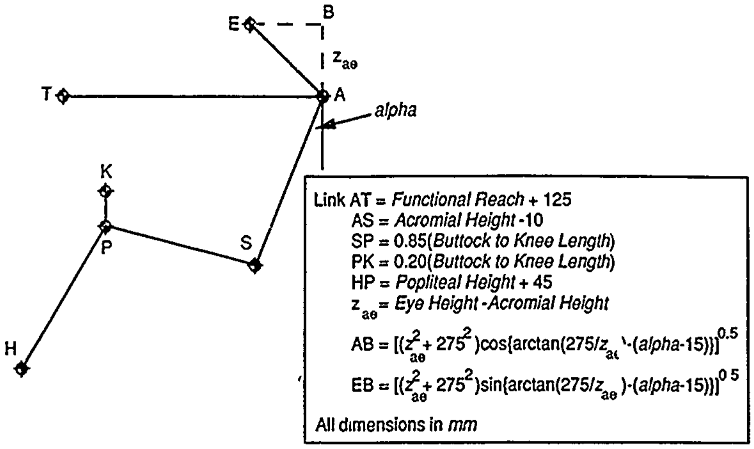

Figure 2. *Five link sagittal plane model used in SAFT.*

Once the panel reach assessment is complete, reach to the floor line is tested. If the heel point can not be located on the floor line, remaining seat rotation is used in an effort to find an intersection. Finally, the heel point is tested against the pedal adjustment range. Those manikins which fail to reach the rearmost heel position can use seat rotation, up to the maximum allowable, in order to come within range. Those manikins with heel points ahead of the forward limiting heel position, have their heel points brought back to this position. Trunk/thigh and knee angles are checked for range at this stage.

Manikins are classified into groups according to the compatibility test failed. There are four tests for acceptable fit, and manikins may fail one or more tests. The tests are:

Test 1- arm reach to the instrument panel;
Test 2- leg reach to the floor;
Test 3- heel point ahead of the rearmost allowable position; and
Test 4- thigh/trunk angle greater than 85 degrees and knee angle greater than 90 degrees.

4. PROCEDURE

Input data for the monte carlo simulation were obtained from the 1985 survey of Canadian Forces Aircrew [17]. While the data from this survey are for a largely male population, the principle results of the simulation should generalize to any population, regardless of nationality or gender. The correlation matrix, means, and standard deviations for the 5 variables used in SAFT are shown in Table 1.

Simulated fitting trials were run for two geometries. Seat ramp angles of 30 and 110 degrees were used. In both cases the vision line was set at 11 degrees below the horizontal, the trunk link angle (α) at 25 degrees and the thigh link angle (β) at 10 degrees (see Figure 3). The positions of panel, floor and heel ranges, were chosen to achieve approximately 10% rejection rates, from a population of 1900 manikins, for each of the 4 tests of 'fit'.

As a further test on the requirement for a distributed approach, a CADRE of 17 manikins were produced from the percentile values given in Bittner et al. [14] (see Table 2). The percentile values were first turned into z-scores and then into anthropometric values using the means and standard deviations from Table 1. Only the five variables required by SAFT were used in these calculations. Using the same vision angle and seat geometry (i.e. α and β) described above , and with a seat ramp angle of 30 degrees, a workspace was created (i.e. panel, floor and heel locations) that satisfied the complete set of 17 manikins on all tests of fit. This geometry was then tested using 10 independently created populations (N=1000) of SAFT manikins.

TABLE 1

Correlation matrix, means and standard deviations used for the monte carlo simulation in SAFT.

Correlations	Eye Ht. (Sitting)	Functional Reach	Buttock to Knee Lt.	Acromial Ht. (Sitting)	Popliteal Height
Eye Ht. (Sitting)		0.464	0.438	0.823	0.492
Functional Reach			0.721	0.488	0.752
Buttock to Knee Lt.				0.496	0.766
Acromial Ht. (Sitting)					0.491
Mean†	80.6	79.4	60.9	60.6	45.1
Standard Dev.†	3.43	3.88	2.77	2.85	2.27

† anthropometric variables in *cm*.

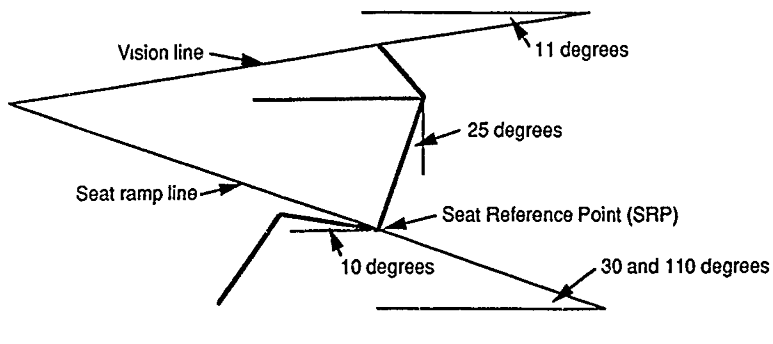

Figure 3. *SAFT workspace geometry.*

TABLE 2

Percentile values used to produce the 17 manikin set for CADRE.

Manikin	1	2	3	4	5	6	7	8	9
Eye Ht. (Sitting)	97.2	93.5	91.2	28.5	93.8	82.8	16.5	87.2	12.8
Functional Reach	97.3	76.3	89.6	92.2	68.2	51.6	58.0	22.9	77.1
Buttock to Knee Lt.	98.5	61.7	81.4	95.6	92.4	16.5	43.6	33.3	66.7
Acromial Ht. (Sitting)	95.7	90.0	86.9	36.8	91.4	75.5	22.0	82.5	17.5
Popliteal Ht.	97.6	63.8	96.7	90.7	66.7	58.6	38.3	11.7	88.3

Manikin	10	11	12	13	14	15	16	17
Eye Ht. (Sitting)	83.5	17.2	6.2	71.5	8.8	6.5	2.8	50.0
Functional Reach	42.0	48.4	31.8	7.8	10.4	23.7	2.7	50.0
Buttock to Knee Lt.	56.4	83.5	7.6	4.4	18.6	38.3	1.5	50.0
Acromial Ht. (Sitting)	78.0	24.5	8.6	63.2	13.1	10.0	4.3	50.0
Popliteal Ht.	61.7	41.4	33.3	9.3	3.3	36.2	2.4	50.0

5. RESULTS

The interaction between workspace geometry and anthropometry is demonstrated by the Test 1 (reach to panel) failures for seat ramp angles of 30 and 110 degrees (see Figure 4). For the 30 degree seat ramp angle, the surface of separation between manikins that pass Test 1, versus those that fail, can be described by a linear relation between *Eye Height (Sitting)* and *Functional Reach* (with a small effect due to *Acromial Height*). For this geometry, Test 1 failures have little or no dependency on the remaining anthropometric variables. A discriminant analysis [18] confirmed this claim (a linear discriminant function in *Functional Reach* and *Eye Height* achieved close to perfect discrimination). Note that the rejection region spans a large part of the range of both variables, hence, incompatibility is not simply a function of being *large* or *small* but rather depends on a critical combinations of the two variables. For the 110 degree seat ramp (typical of ejection seat geometry), the rejection region appears in a different part of the anthropometric domain. Again the separation boundary is largely linearly dependent on *Functional Reach* and *Eye Height*, although the partial overlap between the rejection and acceptance regions in Figure 4 suggests other dimensions are involved. A discriminant analysis showed that a linear discriminant function in *Functional Reach, Eye Height* and *Acromial Height* could precisely categorize the data into acceptable and rejection regions. Note from Figure 4, that the Test 1 failures for the 110 degree seat ramp geometry can be separated largely on the basis of *Functional Reach* alone.

Whereas panel reach depended on linear transformations of two or three anthropometric variables, the location of heel points on the floor line involves non-linear transformations (i.e. sine and cosine relationships) and depends on all five anthropometric variables. In Figure 5, the Test 3 failures are plotted against three of the five anthropometric variables used in SAFT. Examination of these data under various axes combinations and rotations, using a 3-dimensional data analysis package (MACS PIN 2.0 [19]), failed to disclose a simple structure for the boundary of separation between the Test 3 failures and the region of acceptable characteristics. Within the domains examined, the region of Test 3 failures and the region of acceptable anthropometric characteristics are highly confounded. Both standard discriminant analysis [18] and canonical discriminant [20] analysis were performed on these data. The Test 3 failures could not be separated from the acceptable region by either of these linear techniques. This is demonstrated in Figure 6, where the first two canonical variables are plotted for each category of fit. No other combination of canonical variables proved to more successful in separating the data. There is some evidence that the linear transformations of the canonical discriminant analyses have approximated the surface of separation in parts of the domain (i.e. there is an edge appearing between the 3rd and 4th quadrants in Figure 6), however, the surface of separation can not be described in terms of a single linear relationship. This is further demonstrated by Figure 7 which provides a view of the domain defined by the first three canonical variables.

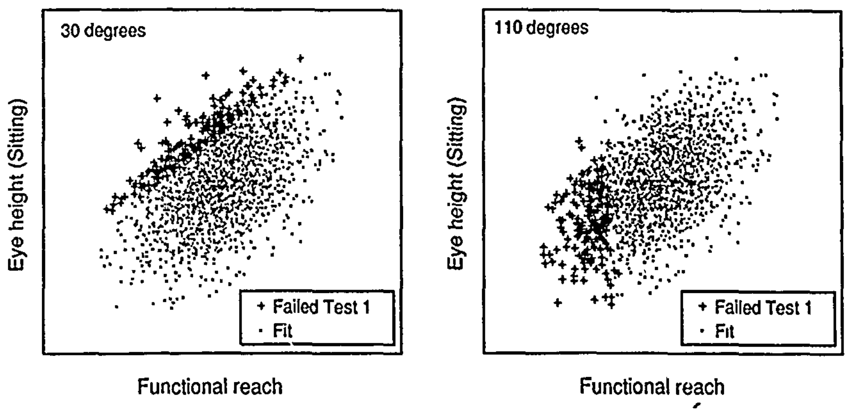

Figure 4. *Test 1 failures for 30 and 110 degree seat ramps.*

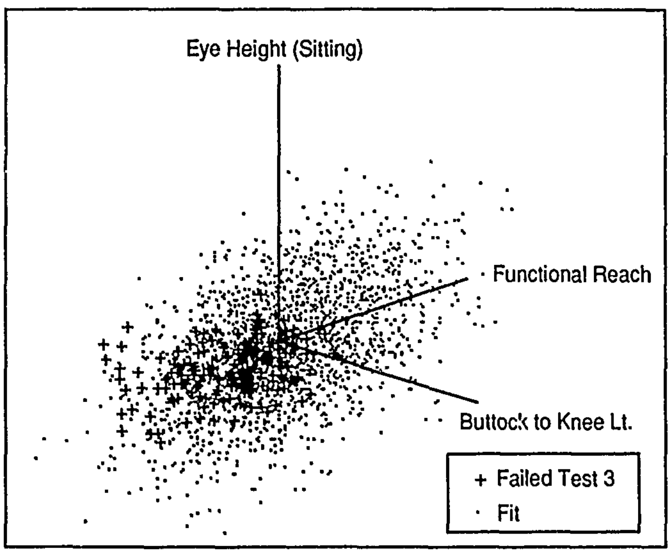

Figure 5. *Test 3 failures for the 30 degree seat ramp.*

The rejection rates for each of 10 independent populations of SAFT manikins are shown in Table 3. For a geometry that satisfied the CADRE 17-member set, it can be seen that Test 3 failures exceeds the nominal 5-6% rejection rate expected from the use of CADRE, while Test 1 failures fall considerably under this rate.

TABLE 3

SAFT rejection rates for a workspace geometry determined from the 17-member CADRE of manikins.

Run Number	1	2	3	4	5	6	7	8	9	10	Mean	S.D.
Test 1	2.0	1.5	2.4	2.4	2.3	1.8	2.4	2.3	1.9	2.4	2.1	0.32
Test 2	3.5	3.0	3.7	2.5	2.6	3.6	4.0	3.6	2.5	2.9	3.2	0.55
Test 3	11.6	9.7	12.5	10.4	12.8	11.3	10.1	11.0	12.4	9.1	11.1	1.26
Test 4	4.4	5.4	5.6	6.2	5.6	7.0	5.3	5.8	7.7	6.9	5.9	0.93

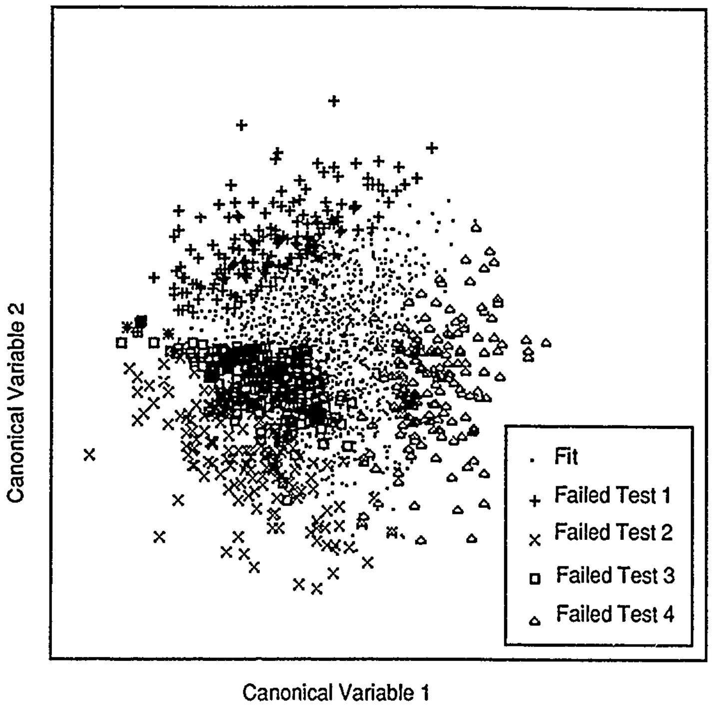

Figure 6. *Canonical discriminant analysis (30 degree seat ramp).*

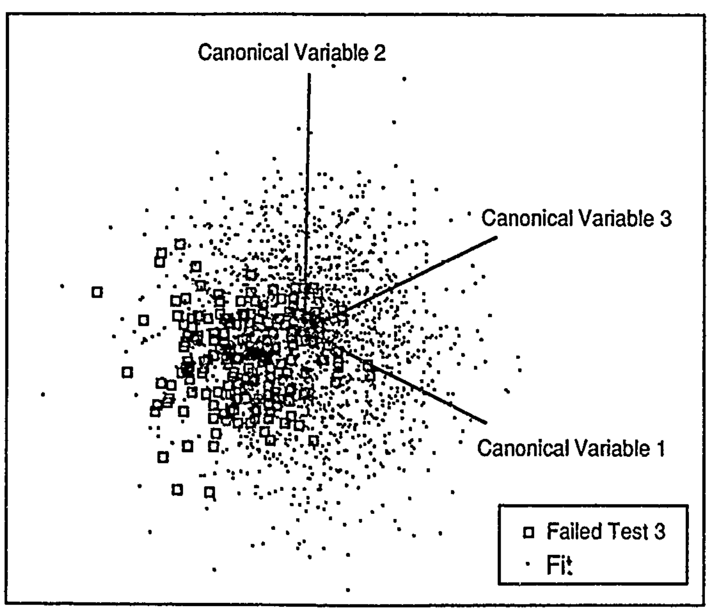

Figure 7. *Canonical domain for Test 3 failures (30 degree ramp).*

6. DISCUSSION

The application of SAFT to the relatively simple workspace geometries reported here, clearly demonstrates the 2 major claims of this paper: (1) that the anthropometric attributes that determine membership in a particular category of 'fit' is dependent on the specific workspace geometry; and (2) that rejection regions can be characterized by complex non-linear surfaces of separation within the anthropometric data space. Therefore, in view of these characteristics, it is not surprising that traditional techniques for the application of anthropometric data to design have been found to be inadequate in some situations [3]. The development of selection criteria, particularly those intended to ensure compatibility with existing workspace designs, is seen to be a related issue. In both design and selection, these complex interactions are not to be ignored.

The SAFT simulation program was written to demonstrate the nature of this problem and to create an environment where methods could be investigated for characterizing the regions of rejection for various workspace geometries. Although linear techniques such as discriminant analysis achieved good categorization for certain rejection regions (e.g. reach to panel), they failed for others (e.g. pedal reach). Some tentative efforts have been made to use neural network methods to partition the space. Early efforts have been encouraging, and there are plans to continue with this technology. Alternatively, it is possible that linear methods might be made to work if appropriate transformations are first made to the data. This avenue will also be explored further.

If it is accepted that 'compatibility' depends on the interaction between an operator's anthropometric characteristics and the workspace geometry, then it raises questions about the role of context free (i.e. geometry independent) selection criteria. On the other hand, selection criteria might be derived from the characteristics of one or more existing workspaces, or from geometries that are found in various design standards (e.g. [21]) or human engineering guidelines (e.g. [22]). Such geometry specific selection criteria may prove to be excessively restrictive if the rejection region of an old geometry is the acceptance region of a new geometry. This, however, should not be seen as a choice between one method or the other. It is suggested that an integrated approach to selection and design requires both approaches, that is: the establishment of a simple set of context free selection/design criteria, and the development of compatibility 'templates' for individual workspace geometries and the application of these templates in assigning operators to workspaces.

The context free selection/design criteria should be as simple as possible [23] and are intended to truncate the distribution of anthropometric characteristics and so avoid extreme outliers. As long as appropriate multi-variate and distributed methods are used, this strategy should provide the greatest freedom for designers. Ideally, these context free criteria should enclose a proportion of a target population which provides a suitable pool of operator candidates for training. If the purpose of these criteria is merely to avoid extreme outliers, then a simple uni-variate approach to setting rejection ranges may be adequate. This truncated multi-variate distribution then becomes the basis for future design exercises. Design for safety or critical performance of all future equipment should accommodate a nominal 100% of the operator population specified by these criteria. Alternatively, anthropometric limits will be established for those workspaces that do not achieve this goal. Future design efforts should also concentrate on developing workspaces that are more uni-variate in their compatibility requirements, for example, through the use of seat mounted controls and helmet mounted displays. Also certain geometries (e.g. panel reach for the 110 degree seat ramp-see Figure 4) can facilitate this process by reducing compatibility requirements to dependencies on single anthropometric variables.

The development of compatibility templates for specific workspace geometries is an essential adjunct to the use of the context free criteria in design. These templates should focus on those aspects of compatibility that are essential for the safe operation of the equipment or are essential for achieving a minimum acceptable level of performance. Each potential operator should be screened against the appropriate template before assignment to a specific workspace. These templates should only be required for existing workstations or for those new workspace designs that are unable to achieve critical operation by 100% of the operator population. In the short term, these templates will establish the effective selection criteria. Until such time as new geometries achieve critical operation by 100% of the context free distribution, the 'working' selection criteria will be established by the intersection of sets of acceptable anthropometric characteristics (i.e. the templates) derived from a specific group of workspaces. This group will include all workspaces on the operators' critical career path (i.e. training aircraft), plus a selection of operational workstations that might range from a single type, to all types in the inventory. If selection and design are tied together in this fashion, the process should evolve over time from an initial set of quite complex rules for selection, as established from the templates, to the simple context free criteria discussed above.

It has been argued throughout this paper that a multi-variate distributed approach must be taken in the application of anthropometric data to design. Such an approach is also critical in developing selection criteria, particularly in the establishment of compatibility templates. Although a CADRE of manikins chosen in the style of Bittner et al. [14], may be adequate for establishing the critical dimensions of a workstation, this limited representation of the data space has little interpretative power once rejection regions cut the enclosing boundary. This was demonstrated in the use of the 17-member CADRE to design a workspace which was subsequently tested against samples drawn from throughout the anthropometric data space. The discrepancy between the SAFT rejection rates (see Table 3) and the predicted 6% rejection rate for CADRE, suggests the existence of either Type A or B (Figure 1) rejection regions for this geometry. For those 'rejection' criteria that imply impaired operability rather than system failure or dangerous operation, the requirement to keep all such regions external to the enclosing boundary can result in overly conservative design solutions. Such conservatism is not without cost as it leads to greater size, larger ranges of adjustment and added complexity.

7. CONCLUSIONS

Although it is recognised that physical compatibility with a workspace is likely to depend on an interaction between an operator's anthropometric characteristics and workspace geometry, traditional methods for the application of anthropometric data to both design and the development of selection criteria appear to place little emphasis on this knowledge. The geometry specific nature of anthropometric compatibility, and the need for a non-linear multivariate approach to design, were demonstrated through the use of a computer simulation program called SAFT (Simulated Anthropometric Fitting Trial).

In view of these characteristics, it is suggested that a two tiered approach to selection/design is required, namely: the development of simple geometry free criteria for use in design and subsequently for selection; and a set of compatibility 'templates' for screening potential operators for their suitablity to occupy specific workspaces. In the short term, selection criteria would be determined from the intersection of some set, or subset, of the acceptable regions defined by these templates. Such criteria are likely to be complex, non-linear, multivariate functions of anthropometric variables. But if new workstations are designed in accordance with the simple geometry free criteria, then the requirements for selection should relax over time to match these same criteria. It is likely, however, that compatibility templates will still have to be developed for certain workspaces within a class of equipment, possibly due to constraints or trade-offs which occur in the design process. The restrictions imposed by these templates may become selection criteria for just that item of equipment (career streaming), or they may become part of the general criteria for selection ('fit to fly all'), depending on resource utilisation policy.

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NORMES ANTHROPOMETRIQUES ET SELECTION DES PERSONNELS NAVIGANTS FEMININS FRANCAIS

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RESUME -

Les normes morphologiques actuellement en vigueur dans la sélection des pilotes sont très restrictives, et ne correspondent pas aux besoins réels de conception ergonomique des matériels futurs.
L'évolution des variables morphologiques des populations concernées au cours du temps a nécessité la mise en oeuvre de méthodes statistiques prédictives de la morphologie des utilisateurs aux échéances des prochaines décennies.
Actuellement la sélection se fait sur cinq mesures anthropométriques : la stature, la taille-assis, la longueur du membre supérieur, la longueur fesses-genoux et la hauteur genoux-sol..., ce qui conduit à exclure un certain nombre de candidats. Ce phénomène ne fera que s'accentuer pour les matériels existants compte tenu des différences de morphologies observées avec l'apparition d'un recrutement de personnels navigants féminins militaires.
Des données disponibles dans la Banque de Données ERGODATA, sur les populations masculines et féminines sont présentées. Elles montrent que les normes actuellement en vigueur excluent une partie de ce potentiel de recrutement (jusqu'à 20 % des femmes). Un projet d'enquête à large échelle sera proposé, et plus particulièrement pour les personnels militaires de l'aéronautique se destinant à une carrière de pilotes.

1 - INTRODUCTION -

Les normes morphologiques actuellement en vigueur dans la sélection des pilotes sont très restrictives. Elles apparaissent, sous le prétexte de contraintes techniques, plus souvent imposées par la conception des matériels actuels que par les capacités et les besoins réels des utilisateurs.

Cinq dimensions anthropométriques sont officiellement admises (1) et constituent des normes d'exclusion, non seulement pour les personnels masculins actuellement recrutés, mais peut être plus encore pour les personnels prévisibles aux échéances d'utilisation des équipements des années 2000-2015.

Naturellement, les personnels féminins, dont les pourcentages de recrutement sont de plus en plus importants, près de 14% dans l'ensemble de la population générale militaire française selon les statistiques les plus récentes, n'échappent pas à ces contraintes d'exclusion. Ceci apparaît d'autant plus paradoxal que l'on ne dispose pas de données suffisantes, en nombre et en qualité, pour bien définir l'importance de la variabilité statistique de cette nouvelle population. Il importe donc dès à présent :

- d'établir des modèles prédictifs de l'évolution démographique et morphologique de la population des opérationnels et dans le cas particulier des personnels navigants, hommes et femmes, pour les 20 ans à venir ;
- d'évaluer l'importance de la variabilité créée par une population définie sur de nouveaux critères de recrutement, reposant beaucoup plus sur les capacités opérationnelles et les exigences de la mission, les critères médicaux, psychologiques, physiologiques, les niveaux de qualifications techniques et scientifiques, que sur des frontières morphologiques intangibles !
- de mettre en évidence l'importance des pourcentages d'exclusion de personnels à partir de ces critères purement morphologiques, malgré un potentiel réel d'aptitudes médicales et techniques, en considérant que les personnels féminins et masculins font partie d'une seule et même population statistique ;
- enfin d'entreprendre les études et enquêtes nécessaires à l'acquisition des données manquantes, particulièrement pour les personnels féminins, dès 1990.

2 - MODELES PREDICTIFS DE L'EVOLUTION MORPHOLOGIQUE -

2.1 - Déterminations sur la stature -

La détermination de mesures corporelles longitudinales, transversales et périmètres, constitue l'élément d'information nécessaire et indispensable à la définition de l'encombrement statique du pilote - homme ou femme - pour la conception des futurs postes de pilotage des aéronefs. Parmi les principaux critères anthropométriques du corps humain, la stature constitue une mesure longitudinale de référence, biologiquement complexe car composée de la somme de différents segments anatomiques, dont l'accroissement séculaire a toujours fait l'objet de nombreuses spéculations.

En France, l'évolution de la stature constatée depuis le début du siècle, comme dans de nombreuses autres nations, dépend de plusieurs facteurs plus ou moins liés entre eux (2), qui concernent :
- l'influence de l'âge, du sexe, de l'origine géographique, des milieux socio-économiques, culturels et qualification professionnelle (2, 3, 4, 5, 6, 7).
- le développement démographique global de la population et les modifications des dimensions de la famille (8), ;

En fait, on observe que la stature moyenne n'augmente pas d'une manière systématique et surtout de manière synchrone, entre les populations, au cours du temps. Pour établir, à titre d'exemple et de méthode, un modèle prédictif d'évolution de la stature moyenne des pilotes français aux échéances 2010-2015, on peut considérer deux étapes distinctes.

La première étape consiste à recueillir les valeurs moyennes de la taille depuis les années 1940 jusqu'à nos jours, la sélection des pilotes étant effectuée à partir de critères bien définis, âge compris entre 19 et 40 ans, et surtout niveau scolaire.

A ce propos, on peut souligner qu'une évolution s'est manifestée de façon très significative dans le recrutement des pilotes. La dernière enquête réalisée dans le courant de l'année 1989 (9) montre que 51% des pilotes examinés possèdent un niveau supérieur au Baccalauréat, ceci étant d'autant plus marqué chez les sujets les plus jeunes : 61% d'élèves et de stagiaires sont dans ce cas, alors que cela ne concerne que 42% des pilotes confirmés. Si on se reporte aux niveaux scolaires les plus représentés dans les enquêtes antérieures, on constate une évolution du recrutement vers des qualifications supérieures au Baccalauréat. Lors des enquêtes de 1965 et 1972, la majorité des pilotes possédaient un niveau inférieur ou équivalent à ce diplôme et en 1981 la tendance étant au niveau du Baccalauréat ou ce diplôme plus une année d'étude.

L'évolution des valeurs moyennes de la stature des pilotes français est représentée graphiquement (figure n°1) en comparaison de celle d'autres groupes d'âges équivalents, définis, à titre d'exemple, à partir de niveaux et de critères de sélection différents :
- étudiants ingénieurs de très haut niveau (polytechniciens),
- étudiants de faculté,
- jeunes hommes issus de la population générale (soldats du contingent),
- jeunes hommes, ouvriers, sans qualification.

Cette présentation permet de situer l'évolution de la stature d'un groupe, lui-même constitué après une très forte sélection, les pilotes, par comparaison à celle de ces autres catégories, aux mêmes périodes. L'opposition entre les "élèves ingénieurs" et les ouvriers non qualifiés ou "jeunes militaires" est choisie délibérément, pour faire apparaître les grandes variations staturales déjà observées au sein d'une même population : les hommes. Dans cette période 1940-1990, elles déterminent les limites maximales et minimales de la stature moyenne de populations masculines à différentes périodes d'enquêtes.

Dans une deuxième étape, on effectue une modélisation statistique de l'évolution probable de la stature moyenne des pilotes français à partir de 1990, à l'échéance des années 2010-2015. Elle repose sur deux hypothèses fondamentales :
- la définition d'un seuil maximal biologique,
- le choix de la relation algébrique donnant la meilleure évolution au cours du temps.

D'un point de vue biologique il est probable, compte tenu des données antérieures, que la stature moyenne des pilotes français ne dépassera pas celles des étudiants de très haut niveau. Cette valeur, vraisemblablement inférieure à 180 cm. a été choisie, dans l'hypothèse présente, à 179,8 cm. Il faut toutefois souligner qu'elle sera de toute façon supérieure à 176 cm., seuil qui devait être atteint par la population plus générale des jeunes militaires du contingent vers l'an 2000.

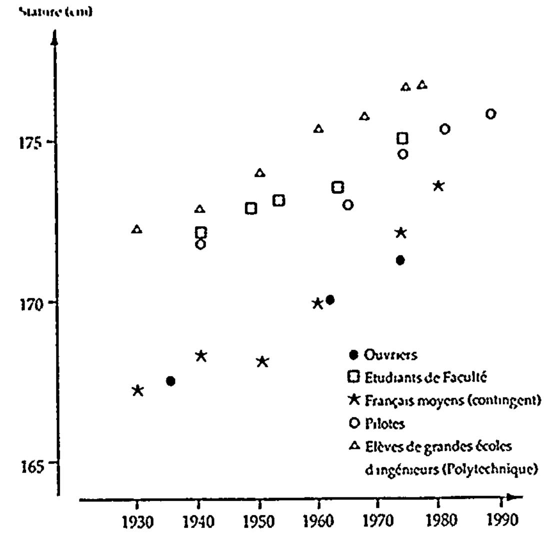

Figure n° 1
Evolution de la stature moyenne des pilotes français entre les années 1930 et 1990, comparée à celles de divers autres groupes définis à partir de critères socioprofessionnels différents

Dans la mesure où les critères de sélection des élèves pilotes ne changeraient pas exagérément, ou guère différemment de ce qui a été évoqué plus haut, on peut effectuer une modélisation de l'évolution de la stature moyenne à partir de valeurs relevées depuis 1965, jusqu'en 1989, et pour lesquelles on observe un accroissement staturo-pondéral notable (tableau n°1).

Années / Mesures	1965	1972	1981	1989	1995 (prévisions)		2015 (prévisions)	
					- 30 ans	+ 30 ans	- 30 ans	+ 30 ans
Poids (kg) m	68,9	68,1	69,8	71,6	70,0	73,0	70,5	74,0
Poids (kg) σ	7,9	8,7	8,5	8,3	8,7	8,7	8,9	8,9
Stature (cm) m	173,1	174,7	175,3	175,9	176,8		178,0	
Stature (cm) σ	6,0	5,7	5,3	6,7	5,8		6,0	

Tableau n°1

Moyennes et écarts-types pour le Poids et la Stature des pilotes français ; valeurs mesurées jusqu'en 1989 et prévisions aux échéances 1995-2015.

D'une façon générale, les accroissements de la stature moyenne diminuent au cours du temps quand on passe des catégories socioculturelles ou socioprofessionnelles les plus élevées au catégories moins élevées, mais cette diminution n'est pas linéaire. Dans ces conditions on choisi un modèle de "courbe de croissance" dont la valeur moyenne ne dépassera pas le seuil biologique fixé (a = 179,8 cm.). On regroupe les valeurs moyennes des pilotes français autour d'une portion terminale de courbe logistique dont l'équation est de la forme :

$$\text{Log}\ \frac{\text{Stature}}{a - \text{Stature}} = \alpha t + \beta$$

dans laquelle : α et β sont deux paramètres à déterminer, a étant la limite du seuil biologique fixée arbitrairement ; α et β peuvent être calculés à partir des données du tableau n°1 et t représente le temps en années.
Cette méthode conduit aux estimations suivantes :
- 1995 : stature moyenne égale à 176,8 cm.
- 2015 : stature moyenne égale à 178 cm.

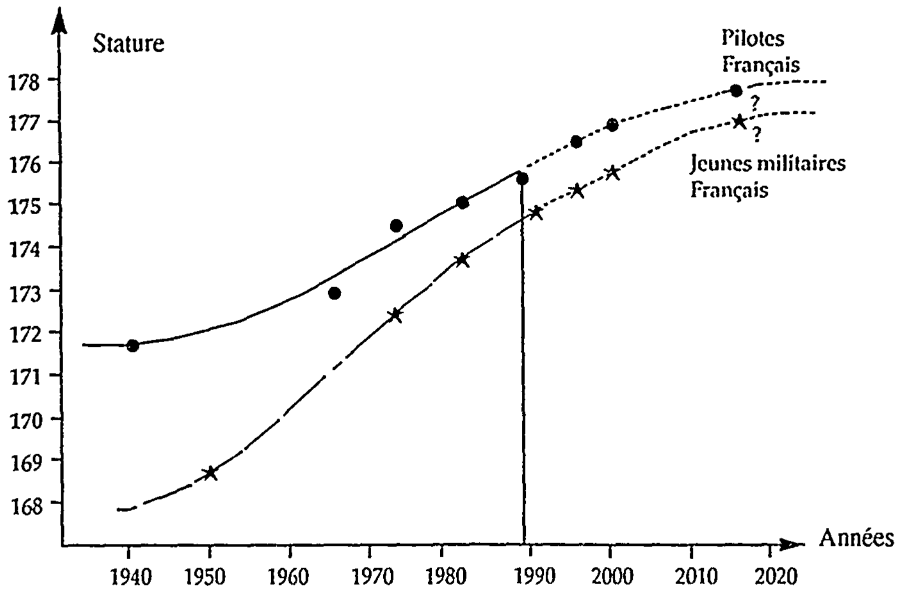

Figure n° 2
Valeurs moyennes de la stature des pilotes français, âgés de 19 à 40 ans, entre les années 1940 et 2015.
Courbe comparée à la population masculine militaire française générale.

Bien entendu, la modification des niveaux d'études, récemment observée en 1989 dans le recrutement, peut modifier légèrement ce pronostic, mais il est encore prématuré de l'intégrer à ce modèle.

2.2 - Méthode d'estimation sur des mesures segmentaires -

En raison de l'existence de normes limites sur les mensurations segmentaires, ayant une valeur significative dans la réglementation actuelle de la sélection des personnels, il apparaît nécessaire d'appliquer le modèle prédictif à certaines dimensions considérées comme mesures de base (1).

Ainsi à titre d'exemple, une estimation de la hauteur de la taille-assis (TA) s'obtient à l'aide d'un indice de proportion (Indice Cormique Ic) défini par la relation :

$$Ic = \frac{100 - \text{Taille Assis}}{\text{Stature}}$$

Cet indice fournit les proportions relatives de la hauteur du buste pour une stature donnée.

Pour les pilotes, entre 1965 et 1981, cet indice a subi des fluctuations et on choisit une valeur moyenne de Ic = 52,6. On peut estimer alors une valeur de la taille-assis redressé de :

- 93cm pour 1995,
- 93,5 cm pour 2015.

On observe une légère augmentation de cette dimension, qui confirme le fait qu'un accroissement statural entraîne une apparente diminution relative de la hauteur du tronc au profit d'une augmentation de la longueur des membres inférieurs, comme cela est illustré figure n° 3 pour la population générale des jeunes adultes.

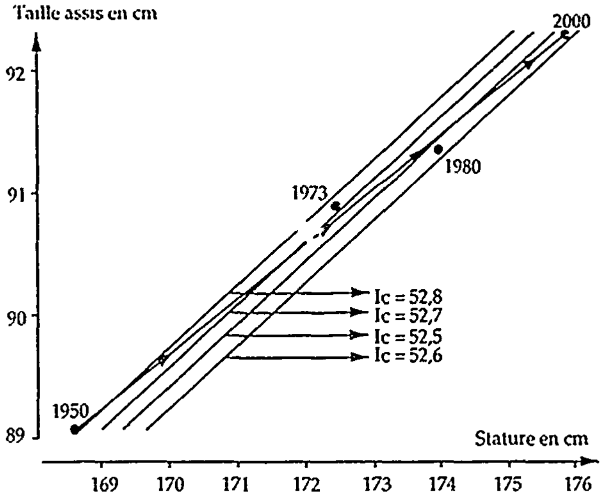

Figure n° 3
Evolution des valeurs moyennes de la stature en fonction de la taille-assis
au cours du temps, sur une population générale.

3 - NORMES DE SELECTION ET VARIABILITE MORPHOLOGIQUE D'UNE POPULATION GENERALE -

Normes de recrutement -

Il existe actuellement dans le recrutement des personnels navigants de l'aéronautique militaire française une contrainte réglementaire (1) particulière à la "constitution physique générale", précisant les valeurs limites de dimensions anthropométriques.

- Une norme A tient compte, pour l'aptitude au siège éjectable dans les avions de combat, de limites minimales et maximales de dimensions segmentaires. Cette norme ne concerne actuellement que les sujets masculins. Les valeurs réglementaires sont les suivants :

Pilotes masculins	mini (cm)	maxi (cm)
Hauteur du corps assis (Taille assis)	80	100
Longueur utile du membre supérieur	60	80
Longueur de la cuisse (distance fesses-genoux)	50	65
Longueur de la jambe (hauteur du genou au-dessus du sol)	45	60
Taille globale (stature)	160	196
Poids	en rapport convenable avec la taille	

On remarquera que la notion de "rapport convenable" du poids en fonction de la taille n'est pas précisée dans le texte réglementaire.

Une norme B - Cette norme ne tient pas compte de l'aptitude à l'utilisation du siège éjectable. Elle concerne donc à la fois le recrutement de personnels féminins et de personnels masculins. Les contraintes anthropométriques ne retiennent que des dimensions globales : taille et poids.

Norme de recrutement sur la taille	mini (cm)	maxi (cm)
Taille des Hommes	160	196
Taille des femmes	155	-
Poids	"en rapport convenable"	

- Variabilité morphologique des personnels masculins et normes limites -

Les données extraites d'ERGODATA (Banque de Données Internationales de Biométrie Humaine et d'Ergonomie) (10) offrent la possibilité de recréer des modèles statistiques de populations de pilotes masculins, avec les dimensions segmentaires considérées.

L'évolution de la stature, telle qu'elle a été décrite ci-dessus (figure n° 2), peut être complétée par les autres dimensions segmentaires définies dans la norme (tableau n°2).

ENQUETES HOMMES	1986 - 1989 (pondéré)				1995 (estimé)				2015 (estimé)			
MESURES	m	σ	5 %	95 %	m	σ	5 %	95 %	m	σ	5 %	95 %
Poids (Kg)	71,60	8,30	57,90	85,30	72,00	8,30	58,30	85,70	73,00	8,90	58,30	87,70
Stature (cm)	175,97	6,75	164,80	187,10	176,80	6,75	165,70	187,90	178,00	6,00	168,10	187,90
Taille-assis redressé	92,05	3,27	86,70	97,40	92,62	3,03	87,60	9760	92,98	3,04	88,00	98,00
Ht yeux-siège	80,61	2,82	76,00	85,30	81,11	2,84	76,40	85,80	81,42	2,85	76,70	86,10
Long. fesses-genoux	59,88	2,20	56,30	63,50	60,13	2,21	56,50	63,80	60,51	2,22	56,80	64,20
Hauteur genoux-sol	55,39	2,18	51,80	59,00	55,60	2,20	52,00	59,20	56,12	2,21	52,50	59,80
Dist. fonctionnelle d'atteinte du M.S.	73,32	3,72	67,20	79,50	73,75	3,74	67,60	79,90	74,38	3,77	68,20	80,60

ENQUETES FEMMES	1985 (3 Armées)				1989 (Armée de l'Air)			
MESURES	m	σ	5 %	95 %	m	σ	5 %	95 %
Poids (Kg)	57,59	7,54	45,10	70,00	59,10	10,35	42,00	76,20
Stature (cm)	163,05	5,97	153,20	172,90	163,34	6,82	152,10	174,10
Taille-assis redressé	86,97	3,23	81,60	92,30	87,10	3,23	81,80	92,40
Hauteur yeux-siège	76,89	3,12	71,70	82,00	77,01	3,12	71,90	82,20
Long. fesses-genoux	56,14	2,81	51,50	60,80	56,25	2,82	51,60	60,90
Hauteur genoux-sol	49,83	2,58	45,60	54,10	49,94	2,59	45,70	54,20
Dist. fonctionnelle d'atteinte du M.S.	64,50	3,66	58,50	70,50	64,64	3,67	58,60	70,70

Tableau n° 2
Données anthropométriques récentes et prévisibles sur les populations militaires :
2a - Pilotes masculins.
2b - Militaires (femmes).

La première partie pour les hommes correspond à un ensemble de mesures réalisées entre 1985 et 1989, sur divers groupes de pilotes et d'élèves pilotes, dont les résultats représentent en quelque sorte une pondération entre différentes enquêtes. Les données 1995 et 2015 sont évidemment estimées sur la base des modèles statistiques établis à partir des données rétrospectives 1940 à 1989. On constate que ces limites jouent sur les percentiles les plus élevés, très largement au-delà du 95ème percentile (figures 4 et 5). Ainsi, après estimation on peut retenir les exclusions prévisibles suivantes.

HOMME	Norme Limite mini.	% 1995 - 2015		Norme Limite maxi.	% 1995 - 2015	
Hauteur du corps assis (T.A.)	80	< 1	< 1	100	99	98
Longueur utile du membre supérieur (bras tendu)	60	< 1	< 1	80	94	92
Longueur de la cuisse (fesses - genoux)	50	< 1	< 1	65	98	97
Longueur de la jambe (genoux - sol)	45	< 1	< 1	60	97	94
Stature	160	< 1	< 1	196	> 99	> 99

Tableau n° 3
Normes réglementaires et percentilages des distributions correspondantes, pour les populations prévisibles de pilotes.

- Variabilité morphologique comparée entre personnels masculins et féminins et normes limites actuelles -

Les enquêtes les plus récentes sur une population générale, non militaire, d'hommes et de femmes datent de 1981 (11). La comparaison des résultats entre ces deux ensembles permet d'apprécier l'amplitude de la dispersion totale possible, dans l'hypothèse maximale pour laquelle il existe une proportion équivalente d'individus dans ces deux groupes (tableau n° 4 et figure n° 6).

	Population générale HOMMES 1981				Population générale FEMMES 1981			
	m	σ	5%	95%	m	σ	5%	95%
Poids	73,3	11,0	55,2	91,5	56,9	10,0	40,4	73,4
Stature	173,1	6,8	161,9	184,3	161,1	6,1	151,0	171,2
Taille-Assis Redressé	91,9	3,5	86,1	97,7	86,6	3,1	81,5	91,7
Hauteur genoux-sol	53,7	2,6	49,4	58,0	49,8	2,4	45,8	53,8
Longueur fesses-genoux	59,7	2,8	55,1	64,3	56,4	2,8	49,8	59,0
Indice Cormique (Ic)	53,9				53,7			

Tableau n° 4
Données anthropométriques pour une population générale française, non militaire.

On retrouve l'écart moyen de 12 cm. habituellement admis entre les valeurs moyennes de la stature et de 5,3 cm pour la taille-assis, avec une amplitude de variation oscillant entre 151 cm. (5%) pour les femmes et 184,3 (95%) pour les hommes.

Bien entendu, si ces deux groupes sont considérés comme constituant un même réservoir potentiel de recrutement, ils représentent une distribution générale, bimodale, ayant les caractéristiques suivantes (tableau n° 5) :

- valeur moyenne résultante comprise entre les deux valeurs moyennes de chacun des groupes de 167,1 cm.sur une population générale civile et 168,6 pour une population militaire mesurée en 1985,
- valeurs des paramètres de dispersion résultants, variance et percentilages, plus élevés que ceux de chacun de ces deux groupes pris isolemment.

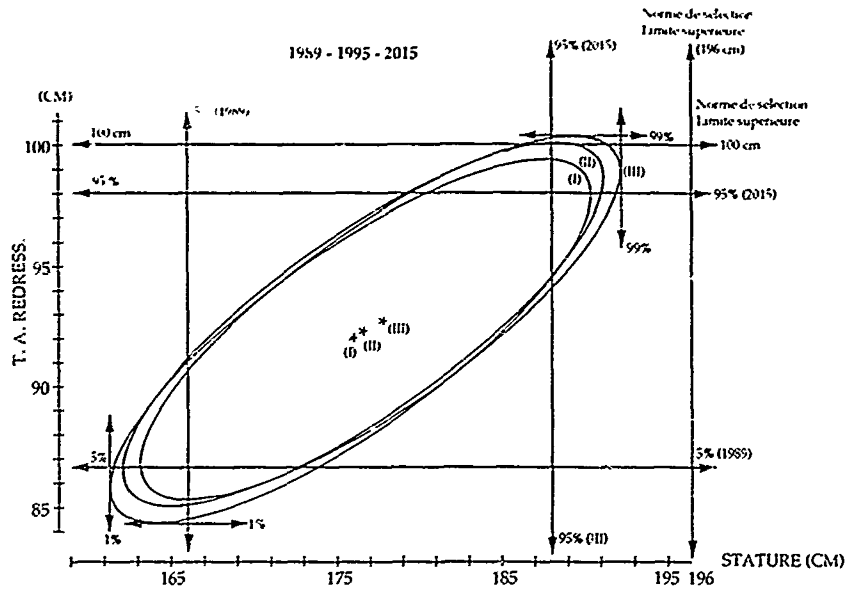

Figure n° 4
Distributions bivariées Stature/Taille-assis observées 1989 (I) et estimées 1995 (II), 2015 (III).

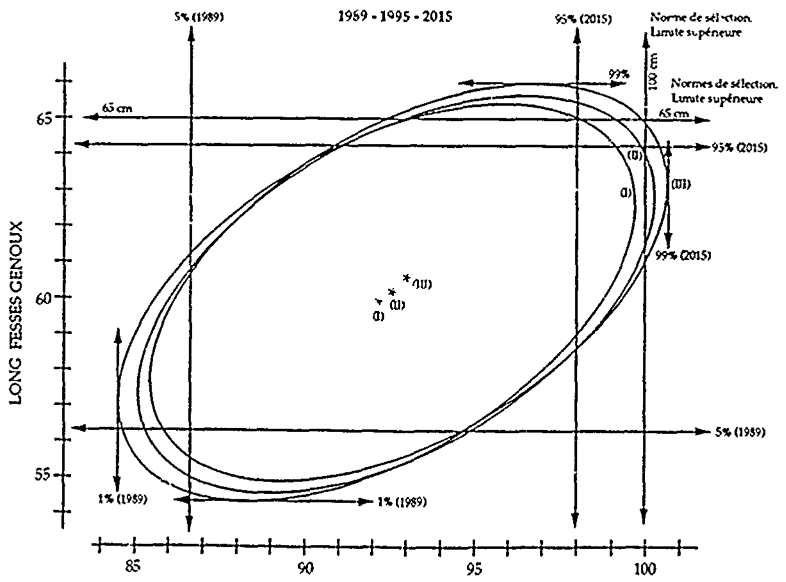

Figure n° 5
Distributions bivariées Taille-assis redressé/Longueur fesses-genoux observées 1989 (I) et estimées 1995 (II) et 2015 (III).

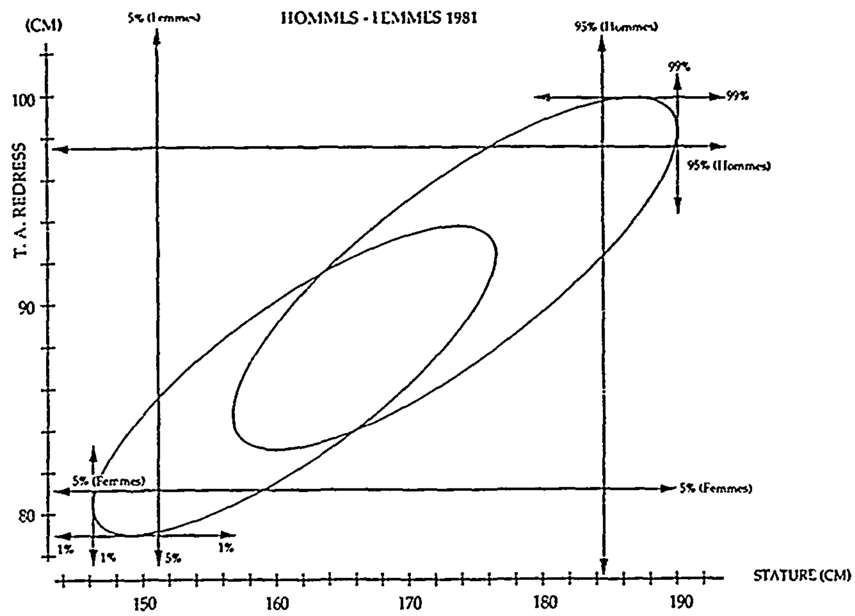

Figure n° 6
Distributions bivariées Stature/Taille-assis comparées entre les hommes et les femmes (en proportions égales), issus d'une même population générale.

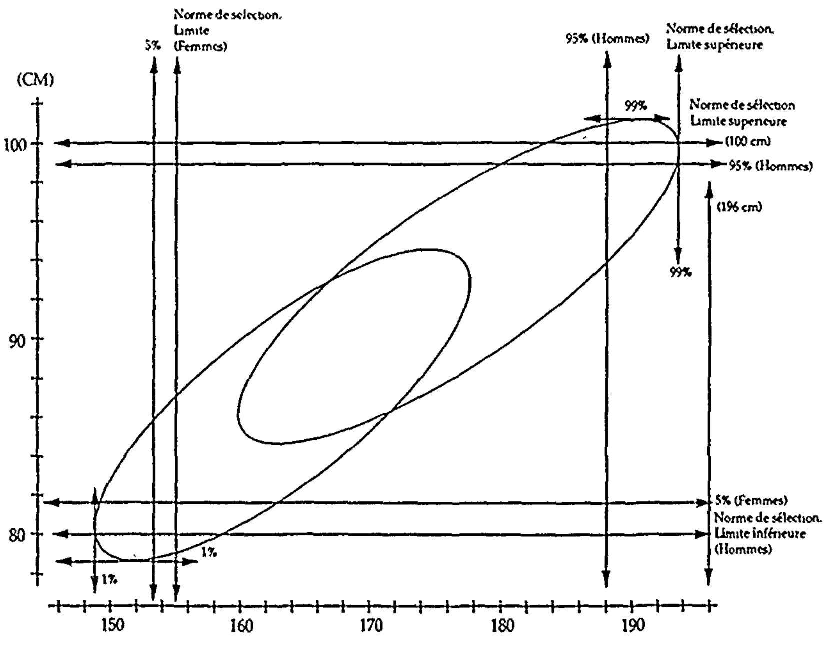

Figure n° 7
Distributions bivariées Stature/Taille-assis comparées entre deux groupes, femmes et hommes militaires, d'âges et de qualifications équivalentes. Recrutement potentiel comme pilotes convoyeurs.

Ainsi une population hommes et femmes regroupés présenterait, pour la stature, les valeurs suivantes.

Valeurs théoriques Hommes + Femmes	m	σ	5 %	95 %
Stature (population générale civile d'après réf. 11)	167,1	9,0	152,3	181,9
Stature (population militaire 1985 d'après réf. 7)	168,6	9,2	153,5	198,8

Tableau n°5
Valeurs théoriques m, σ, 5%, 95% de la stature de populations théoriques composées d'un nombre égal d'hommes et de femmes.

Naturellement ce modèle est tout à fait théorique car le réservoir normal de recrutement de pilotes dans une population ne se situe pas actuellement dans de telles proportions. Cependant rien n'exclut qu'il en soit ainsi dans un tout autre contexte. Le pourcentage actuel de 14% de femmes dans l'armée française ne représente que le résultat, à l'heure présente, d'une sélection dont les critères sont multiples. On peut imaginer que la référence souhaitable se fasse à partir d'un potentiel numérique équivalent de jeunes hommes et de jeunes femmes, qui bien que présentant des qualités intellectuelles et médicales strictement équivalentes ne diffèrent que par les distributions de leurs dimensions anthropométriques.

On est contraint alors de considérer une nouvelle population "anthropométrique" variant, par exemple, du percentile le plus bas des petites femmes 5%, au percentile le plus élevé des hommes de grande taille 95%. Ceci conduit à des amplitudes résultantes importantes (figure n° 7), dont il conviendra de tenir compte moins dans les critères de recrutement, que dans des données de recommandations ergonomiques pour la conception des équipements futurs ou l'utilisation de matériels existants.

4 - CONCLUSION - PERSPECTIVES DE RECHERCHE -

Les résultats qui ont été présentés à partir du fonds de données disponibles dans la Banque de Données ERGODATA, soulignent le risque imposé par l'application stricte de normes de sélection. La seule restriction de 155 cm. sur la stature, pour la population féminine, contraint à une élimination potentielle comprise entre 10 et 12% de candidates (figure n° 7).

Il a clairement été démontré que si l'on ne se plaçait pas dans une perspective de conception de systèmes futurs, mais dans l'esprit d'une adaptation aux limites techniques inhérentes à un matériel existant, on était rapidement conduit à une baisse considérable du capital de recrutement. De telles contraintes imposées sur des limites inférieures et supérieures de critères anthropométriques ne répondent pas à une démarche logique et prospective.

Par la combinaison multivariée de mesures anthropométriques, avec le jeu des intercorrélations, on pourrait réaliser de façon théorique une élimination de près de la moitié d'un effectif de candidats, parfaitement aptes par ailleurs selon les autres critères, médicaux ou opérationnels (12). De ce fait il convient de s'orienter vers une tendance qui s'appuierait non sur des contraintes aveugles de sélection morphologique, mais plutôt sur des recommandations ergonomiques. Une variabilité morphologique de référence, pourra, dans un tel contexte, évoluer entre un petit percentile féminin, à définir (5% ou peut-être moins) et un grand percentile masculin, (95% ou plus). Cela conduira à une amplitude résultante considérable, mais qui se révèlera beaucoup plus réaliste en reflétant parfaitement la véritable variation biologique.

Cependant un tel objectif ne peut s'atteindre sans données réactualisées, fiables, complètes, à partir desquelles des modèles prédictifs d'évolution morphologique pourront être établis, pour les années 2000 - 2015, sur une population statistique Hommes-Femmes confondus. Ce projet se met en place,

et une vaste enquête biométrique sur les populations militaires féminine et masculine des trois armes . Terre - Air - Mer dans l'Armée Française, sera réalisée et exploitée au cours des deux années à venir.

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THE APPLICATION OF USAF FEMALE ANTHROPOMETRIC DATA TO IDENTIFY PROBLEMS WITH THE INTRODUCTION OF FEMALE AIRCREW INTO THE ROYAL AIR FORCE

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SUMMARY

The Royal Air Force (RAF) decided in 1989 to recruit female pilots and navigators. Since there is little statistical data on the distribution of the critical body dimensions for the UK female population the USAF female anthropometric data has been employed to predict the effects of imposing the present RAF minimum selection limits on the female population. This paper discusses these predictions and considers the effects for individual aircraft types. Certain questions are raised concerning limb strength related to aircraft controls and to the possible requirement for a minimum weight for ejection seat occupants. The USAF female data so far employed has only been from the published percentile tables. Further studies will be conducted using the raw data transferred from the US AMRL Data Bank Library to the Institute of Aviation Medicine computer.

The Royal Air Force (RAF) made the decision in 1989 to recruit female pilots and navigators. They will fly in aircraft without a combat role. In practice this opens up a wide range of aircraft from all training aircraft, transport aircraft, search and rescue helicopters to fast-jet aircraft as instructors.

Prior to 1989 the only female aircrew in the RAF were Air Loadmasters on the VC10 transport aircraft. Air Loadmasters (male and female) are required to have a minimum stature of 1575 mm and those close to this extreme are subjected to a vertical reach test. This requirement is to ensure that dinghies can be extracted from roof stowages.

The Royal Air Force's only experience of female flightdeck aircrew was in the University Air Squadrons (UAS). Here students fly in the side-by-side two seat Bulldog trainer. Since these civilian students are not necessarily guaranteed an Air Force flying career it was decided, for the UAS only, to accept females outside the normal RAF aircrew acceptance limits on condition they fulfilled the lower anthropometric criteria for operating the Bulldog.

It was recommended that, initially, potential female pilots and navigators should meet the present RAF aircrew entry limits. Although there is little statistical data on the distribution of the critical body dimensions for the UK female population the USAF has determined in a US female population (Clauser et al, 1972 [1]) the distribution of sitting height, buttock-knee length and functional reach (amongst many other dimensions) employing almost identical techniques to those used in the RAF. Some of the predicted effects of imposing the present RAF minimum aircrew selection limits on this female population are given in Table 1. The predictions are based on the USAF published percentile tables and consider each dimension independently.

TABLE 1. Proportion of Females (USAF Survey) which would be Excluded by Present RAF Aircrew Minimum Entry Limits

Dimension	RAF Limit (mm)	Proportion of Female Population Excluded (%)
1. Sitting Height	865	60
2. Buttock-Knee Length	560	30
3. Buttock-Heel Length	1000	Not Available
4. Functional Reach	740	50

Noting that the proportion excluded varies considerably for relatively small changes in these dimensions it is reasonable to conclude that just over half the female population will be excluded from aircrew selection by their small size.

The existing aircrew selection criteria have been set by critical cockpit dimensions of in-service aircraft. Since 1970 all new RAF aircraft have been designed to accommodate the 3rd to the 99th percentile range of key dimensions for the male aircrew population which is reflected in the present RAF standards for acceptance as aircrew. Most in-service RAF aircraft crew stations have been assessed within the last 15 years to determine the aircrew size limitations (Turner, 1986 [3]). Where possible, individual limitations were determined outside the range of normal aircrew entry limitations. Those that have been determined that are relevant to female pilots are given in Table 2. The appropriate percentile from the USAF female population is given for sitting height and functional reach.

TABLE 2. Minimum Value of Critical Body Dimensions for Pilots in Selected RAF Aircraft

Aircraft	Minimum Acceptable Value (mm) (percentile from USAF female population)		
	Sitting Height	Buttock-heel Length	Functional Reach
RAF entry standard	865(60)	1000	740(50)
Jet Provost	860(55)	980	700(15)
Tucano	840	?	?
Bulldog	830(20)	?	?
Chipmunk	840(30)	?	?
Hawk	865(60)	?	?
Tornado	850(45)	?	?
Harrier T4/GR3	870(65)	?	?
Jaguar	850(45)	970	?
Phantom	?	990	?
Jetstream	830(20)	960	?
Hercules	?	980	?
Gazelle	830(20)	960	?
Wessex	860(55)	1020	750(60)

NB. ? No formal lower limit has been determined as no problems were envisaged within the normal RAF male aircrew size range. It should be possible to determine values which would be below the present minimum entry standard.

There are obviously certain aircraft which will accept smaller individuals than the present RAF entry standards permit. It must be remembered that critical training aircraft must be flown before moving on to other types. The Hawk which is the route to high performance ejection-seat aircraft has the same sitting height restriction as the entry limits. To offer female aircrew selective careers on account of size would be discriminating against their male counterparts. However it has always been possible for waivers to be granted to aircrew candidates with excellent potential but who are outside one or more anthropometry limitations. More often than not these waivers are for navigators with short arms or legs.

To date ten females (4 pilots and 6 navigators) have commenced training, some of whom have certain body dimensions below the normal minimum limits. It is not known whether these short individuals will be able to perform their tasks in the crew stations without some restrictions. What is certain is that many items of specially sized aircrew functional clothing will be required for certain roles. This area is discussed in a separate paper (Turner, 1990 [4]).

It is clear that an investigation of the anthropometry limitations for individual aircraft is necessary to determine the acceptable limits for individuals at the lower end of aircrew entry standards. Here it is believed that strength will also play an important role. On some aircraft, such as the Hercules, the pilot has to oppose large asymmetric forces on the tail using the rudder pedals. Are males and females with the same leg length of the same strength?

Another question that has been raised is whether or not a minimum weight is required for females operating in ejection seat aircraft. Certain nations are known to have added weight to the personal survival pack to compensate for the generally lower mass of their aircrew than the UK male population.

The USAF female data so far employed has only been from the published percentile tables. The raw data has however been transferred, on magnetic tape, from the US AMRL Data Bank Library to the Institute of Aviation Medicine's computer. It is intended to investigate, on the data relating to those of white race, relationships between the parameters discussed above. A survey of UK females is soon to be conducted and the USAF data should prove invaluable in determining sampling strategies.

It remains to be determined whether the US and UK aircrew populations are sufficiently identical. The only comparable UK data to that of USAF was from a small sample survey of 113 Royal Navy (RN) female personnel (Reeves, 1986 [2]). Table 3 is a comparison of USAF and RN female percentile values relating to RAF aircrew entry limitations. It is impossible to make too much of the differences because of the small RN sample size. However the differences in functional reach warrant further investigation.

TABLE 3. Comparison of USAF and RN Female Percentile Values Relating to RAF Aircrew Entry Limitations (Mean Values Also Shown)

	RAF Minimum Limit			Mean Value (mm)	
	mm	USAF Female %ile	RN Female %ile	USAF Female	RN Female
Functional reach	740	50	80	741	709
Buttock-knee length	560	30	25	574	577
Sitting height	865	60	40	856	873
Buttock-knee length	1000	-	60	-	989

In summary, the RAF has now accepted females for both pilot and navigator training. Some of the anthropometry problems have been discussed but considerable effort is required to answer uncertainties relating to individuals outside normal aircrew entry limitations and to strength. The USAF female raw data will enable UK to determine the requirements for a female anthropometry study.

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ANTHROPOMETRIC ACCOMMODATION OF FEMALES IN CANADIAN FORCES AIRCRAFT CREW STATIONS

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SUMMARY

To ensure physical accommodation of humans in aircraft crew stations, aircrew traditionally have been selected on the basis of specific standards. To be effective, these standards must be based on anthropometric limitations imposed by actual crew stations. Evidence suggests this generally is not the case. Instead, selection standards have frequently evolved from (1) aircraft design recommendations, which often bear little relationship to the finished product, or (2) anthropometry of existing aircrew, which ignores the issue. Recognizing this problem, the Canadian Forces (CF) has undertaken a large-scale study known as ACCE (Aircrew/Cockpit Compatibility Evaluation). A computer-based modelling strategy was developed to determine anthropometric limitations, on a crew station by crew station basis, and their subsequent effect on accommodation of pilot and navigator populations. The approach is attractive because it encompasses possible multivariate relationships between anthropometry and crew station geometries, and it is sub-population independent; it assumes a *human* anthropometry but is blind to gender, nationality and race-specific differences. The flexibility of this strategy has allowed assessments of *fit* for both female and male populations in two CF aircraft — the CT133 utility jet and the CH136 light observation helicopter. Results show that current CF selection standards do not represent the range of anthropometry these aircraft can accommodate. This leads to biases in selection against females and small males.

1. INTRODUCTION

In the interest of flight safety and mission success, physical incompatibilities between pilots and crew stations should be avoided. Each pilot must be able to meet operational requirements for reach, vision and body clearance at one or more configuration of the seat and the rudder/rotor pedals. For an existing fleet of aircraft, this objective can be met by selecting aircrew appropriately. But to be effective, the criteria for selection must be based on anthropometric limitations imposed by individual aircraft types. Although this is a case of *fitting the pilot to the aircraft*, it cannot be avoided as long as differences among crew station geometries are as prevalent as their similarities.

Use of anthropometry for guiding selection implies that anthropometric limitations imposed by aircraft are known. Yet, relatively little information of this sort is available. A popular assumption is that anthropometric limitations of aircraft are contained within their design specifications. However, this assumption is false due to the realities of aircraft design. Designs can change significantly throughout the design process, making it difficult to assess eventual aircrew accommodation. Only fitting trials can determine if anthropometric design criteria truly have been met.

Even if initial design criteria are met in the finished product, the external validity of the criteria can be suspect. In most cases human anthropometry is described by a limited number of static (i.e., non-interacting) dimensions. It has been shown that such dimensions (e.g., 5th to 95th percentile stature) fail to adequately represent composite human anthropometry [1]. Also, such criteria are often based on particular population parameters: parameters which may change with time (e.g., increases in mean stature) [2].

The most reliable selection method is a *live* fitting trial in which a candidate is physically placed within the crew station. The method is attractive because it is conclusive; it tests the unique physical characteristics of the individual, accounting for effects of clothing and personal equipment, with little or no data analysis [3,4]. However, due to a number of disadvantages, not the least of which is expense, the method usually is not feasible as a universal selection tool [5]. Other strategies are therefore used to select aircrew. The most common selection criteria are minimum and maximum acceptable limits for several anthropometric dimensions [6].

The use of such criteria to select CF aircrew originated in 1966. At that time, several critical incompatibilities between body dimensions of aircrew and geometries of aircraft became evident [7,8]. It was decided that anthropometric standards would be used to screen aircrew candidates and that, until operational requirements dictated otherwise, these standards would be based on results of a 1962 anthropometric survey of Royal Canadian Air Force male personnel [9]. First and 99th percentile values for mass, stature, seated height, thigh length and leg length were used to derive body size ranges for aircrew candidates. Extra tolerances of 2 cm were added to the limits, effectively extending acceptance beyond the dimension ranges of the aircrew population surveyed [10]. Ironically, this strategy ignored the original incompatibilities for which anthropometric selection criteria were deemed necessary in the first place.

With minor modifications, current CF selection criteria are based on those 1966 standards (Table 1). Also, the CF maintains a recruiting policy of *universal assignability*. successful pilot candidates, whether male

or female, must be able to operate any CF aircraft. Considering the origins of the selection criteria and the variability of CF aircraft (with respect to origin, age, size, mission and configuration), the CF accepts aircrew candidates who do not *fit* all CF crew stations [11]. On the other hand, it may reject candidates suitable for all or many of the aircraft. Given that the CF now employs female aircrew, such errors will become more common.

The CF selection standards have been defended on the grounds that they do not differ significantly from the standards of nations which supply CF aircraft [6]. However, in an advisory publication on the topic, the Air Standardization Coordinating Committee (ASCC) has recognized the need to know anthropometric limitations of aircraft, especially as they relate to aircrew/cockpit compatibility and successful exchange of aircrew amongst different military forces [6]. This publication tabulates differences in national aircrew selection criteria and minimally identifies known anthropometric limitations for some crew stations. For a substantial number of aircraft cited, anthropometric limits have not been set. It is therefore imperative that empirical studies be performed which map the anthropometric limitations unique to each aircraft.

Results from such studies could have direct implications for pilot recruitment policies. For example, enforcement of universal assignability using standards that are based on aircraft-imposed limits could severely restrict the number of pilot candidates selected. In fact, the limitations may necessitate mutually exclusive selection criteria for specific aircraft, or show clusters of aircraft that impose similar anthropometric limitations. Such findings could force policies where a pilot's career must follow specific aircraft assignments, or even suggest specific aircraft assignments for sub-sets of the pilot population (e.g., males versus females). Assignment of pilots to international aircrew-exchange programs could also be affected.

	Pilot		*Navigator*	
Dimension	*Min (cm)*	*Max (cm)*	*Min (cm)*	*Max (cm)*
stature (standing height)	157.7	193.1	157.7	193.1
seated height	86.4	100.3	85 1	101.6
buttock-heel length (leg length)	99.6	123.2	99.6	123.4
buttock-knee length (thigh length)	54.6	67.3	54.6	67.3

TABLE 1. CF Aircrew Anthropometric Selection Standards.

The CF accepts that aircrew selection must take into account physical restrictions imposed by crew stations. Hence, it has initiated an Aircrew/Cockpit Compatibility Evaluation (ACCE) to determine anthropometric limitations imposed by CF aircraft. The scope includes all pilot and navigator crew stations since information currently available has come from investigations of specific compatibility problems identified by existing aircrew [12-15]. The results of ACCE are being used in a review of CF aircrew selection standards. This paper offers results from evaluations of the CT133 and CH136 pilot crew stations, performed in support of that effort. For the purpose of this paper, emphasis is placed on describing the differences between two populations (males and females) in each of the two crew stations.

2. STRATEGY

Several obstacles needed to be overcome for ACCE. First, no prescribed method for evaluation was available. Second, evaluation criteria and operational assumptions (e.g., effects of clothing, personal equipment, etc.) had to be established. Third, aircrew task performance criteria for reach, vision and clearance had to be determined. Fourth, critical dimensions of CF crew stations had to be measured and represented in a usable form.

Selection of the Evaluation Tool

Traditional methods for assessment include (1) use of live subjects, anthropometric dummies or partial manikins in real or mock-up environments, and (2) comparison of 2-dimensional drawing board manikins with engineering drawings. These methods were rejected because they do not adequately represent variable anthropometric combinations. Availability, validity, feasibility and cost were other factors that precluded selecting these techniques [16].

Three-dimensional computer modelling was chosen as the primary evaluation tool for ACCE. Depending on the system employed, this tool can be used to model complex individual differences and simulate atypical body structures and functions. Computer graphics and mathematical algorithms can be used to construct and manipulate 3-dimensional human models within 3-dimensional models of the workplace. Human engineering concepts can be incorporated for assessing body clearances, visual restrictions and performance of reach tasks. The tool is appropriate for using standardized evaluation protocols and yields numeric output [17-19]. These capabilities were considered necessary to fully explore the anthropometric limitations of the CF crew station geometries.

To obtain these capabilities, a 3-dimensional modelling software package called SAMMIE (System for Aiding Man-Machine Interaction Evaluation) was chosen [20]. SAMMIE was developed in the late 1960's and early 1970's at the University of Nottingham, U.K. [21]. A modified version of the program, available from Prime Computer Limited, provides the platform for the ACCE evaluation technique.

SAMMIE uses 3-dimensional solids modelling and computer graphics to build and display a human-model (or manikin) within a physical workplace model (Figure 1). The SAMMIE *manikin* is composed of body segments (e.g., head, neck, upper arm, thigh, calf). Segments are defined using data tables that dictate link lengths, segment shapes (depths and breadths), joint angle constraints (movement limitations), and relative joint positions (posture). These tables can be customized to model specific individuals or represent data from various populations. Once a manikin is generated, its body shape and link lengths can be modified individually or according to percentiles calculated from the data tables. Movement of individual links is under the control of joint constraint data which may be changed to simulate various effects (e.g., normal human postures, restrictive clothing).

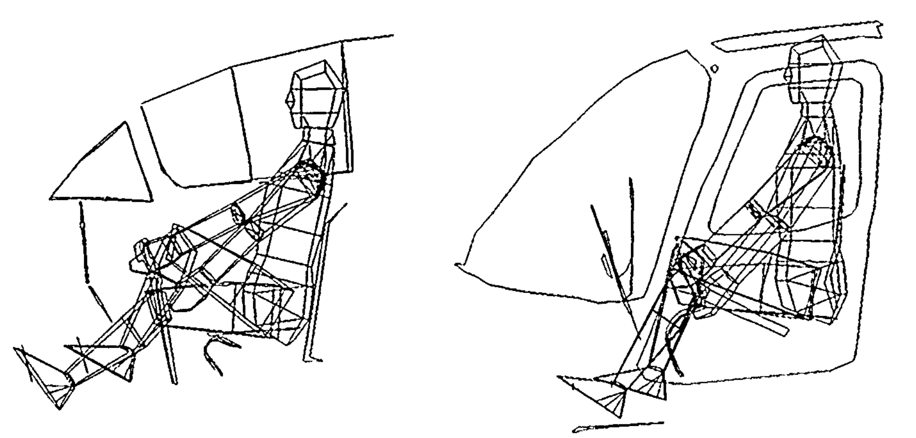


Figure 1. Graphic display of computer manikins in SAMMIE models of CT133 and CH136 aircraft.

The SAMMIE *workplace model* is composed of entities that are built from 3-dimensional primitive shapes (e.g., boxes, cones, cylinders) or irregular solids. Spatial and hierarchical relationships of the entities determine their orientations in the environment. Logical relationships among components allow mechanical functions to be simulated (e.g., movement of a crew seat along ejection rails). Movements of model components can be grouped (e.g., the pilot moves with the crew seat) or can occur independently. The models can be generated interactively or created directly from a data file following off-line preparation [22,23].

SAMMIE offers several important features, most important of which are abilities to test operator reach and vision to specific points in the workplace, and to identify physical obstructions between model elements. Numeric status statements on results, including the orientation and posture of the manikin, allow meaningful evaluations of interactions with the workplace. SAMMIE's display options enhance the power of those evaluations (e.g., sight from the manikin's viewpoint, mirror reflections, simultaneous display of different views, a mesh-grid reference system, Aitoff and Mercator projections).

To ensure that SAMMIE software creates accurate models and contains valid algorithms, the system's capabilities and limitations were evaluated. This included validation of predictions of operator reach [24-26]. Although minor problems were identified, the advantages of this system far outweigh the disadvantages.

Evaluation Technique

The underlying philosophy of ACCE is that anthropometric limitations can be found by (a) defining a multi-dimensional *anthropometric space* and then (b) testing all anthropometry combinations contained in that space for *compatibility* with the crew station. Compatibility, in this case, means that all reach, vision and body clearance requirements are met in at least one *static* configuration of the seat and rudder/rotor pedals in the crew station [27,28]. This philosophy requires three types of information: (i) anthropometry dimensions (including ranges and step-sizes) to define the anthropometry space to be tested, (ii) crew station seat and pedal adjustment parameters (including ranges and step-sizes) to define the static configurations to be tested, and (iii) reach, vision and body clearance tasks and performance criteria needed to evaluate compatibility.

Anthropometry Dimensions: Seven anthropometry dimensions were selected (Figure 2). Sitting height and seated eye height were selected due to their influences on head clearance and vision, respectively. Seated acromion height, biacromial breadth and forward functional reach were selected for their interactive effects on arm reach capabilities. Buttock-knee length and seated knee height were chosen because of their interactive influences on reach to rudder/rotor pedals, and on clearance with the seat pan and front instrument panel. Theoretically, each dimension can range from zero to the maximum allowed by the crew station, but such a strategy was not practical. To limit the computational effort to search for successful combinations yet ensure that the search be as independent of population data as possible, ranges for the dimensions were chosen to lie well outside the extremes of known adult populations. This was achieved by taking the minimum and maximum values cited in the NASA Anthropometric Source Book [29], and extending those ranges by several centimetres. Other techniques not described here were used to optimize the search for successful anthropometry combinations within the defined anthropometric space.

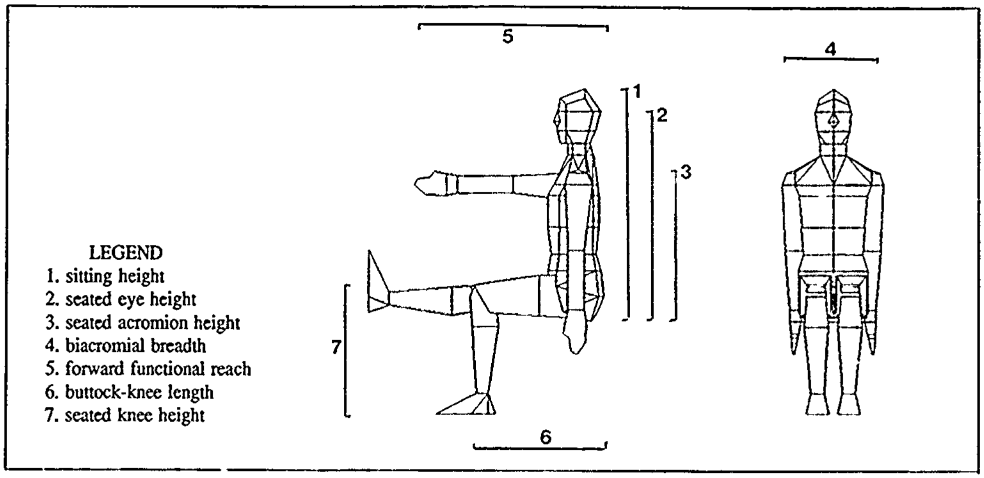


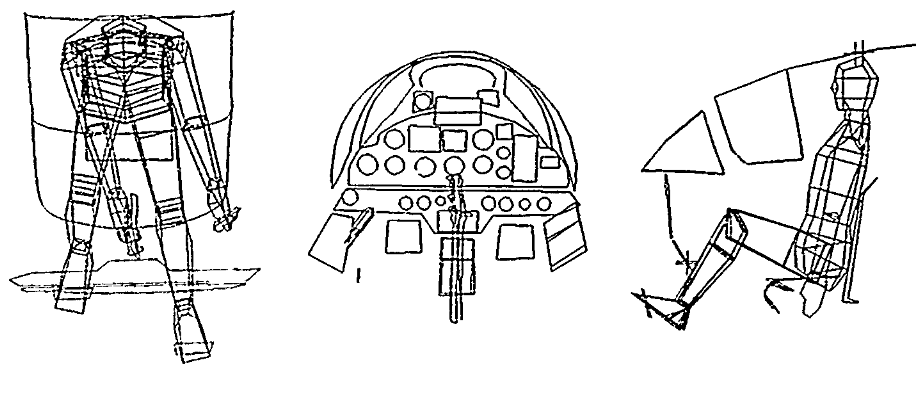
Figure 2. Anthropometric dimensions used to map the physical relationship between anthropometry and crew station geometry.

Crew Station Adjustment Parameters: These included fore-aft seat adjustment, up-down seat adjustment, and fore-aft rudder/rotor pedal adjustment. Rudder/rotor pedal deflection was treated as a sub-set of pedal adjustment; for each pedal adjustment position, reach and clearance tests were performed with pedals at full-forward, neutral and full-aft deflection. This was to ensure full use of the pedals was possible for any given adjustment position. Ranges of seat and pedal adjustment (and deflection) were taken from measurements in real aircraft.

Physical Tasks. Through group interviews with aircrew and follow-up surveys, DCIEM and CF personnel collaborated in drawing up an inventory of physical tasks for each CF crew station. Requirements for reaches, vision and body clearance under normal and emergency (e.g., ejection) conditions were considered. Tasks selected for evaluation were then described according to standard parameters (e.g., grip type, harness restraint), and performance objectives (e.g., allowable joint movements) that could be implemented using SAMMIE sub-routines.

The compatibility evaluation was implemented using SAMMIE. Its protocol resembled that of a *live* fitting trial. The crew station model was arranged with the seat full-down and full-aft, and the rudder/rotor pedals full-aft. The manikin was placed in the crew station model and assigned starting values for each of the seven anthropometry dimensions.

The manikin was subjected to a battery of compatibility tests for reach, vision and body clearance tasks (Figure 3). All tasks were of equal importance; failure to satisfy *any* task constituted incompatibility regardless of the number of successfully completed tasks. By systematically changing each of the seven anthropometry dimensions (e.g., finding minimum forward functional reach required at each combination of acromion height and biacromial breadth), the anthropometric space was searched for compatible anthropometry profiles. Those anthropometry combinations were output to a results file. The crew station configuration was then changed to represent a different seat/pedal combination, and the manikin once more was subjected to the test battery for all anthropometry combinations. This sequence was re-iterated until all crew station configurations had been tested.



Reach to controls   Pilot vision   Body clearance

Figure 3. Physical task considerations illustrated in the CT133 aircraft.

3. METHOD

Anthropometric limitations of two CF pilot crew stations were determined. The CT133 Silver Star, a utility jet, and the CH136 Kiowa, a light observation helicopter, were selected because they are known to pose compatibility problems for both large and small individuals [12,14]. To analyse each of the crew stations, the following activities were performed: (a) create a computer model of the crew station; (b) create and place a manikin within the crew station model; and (c) execute the evaluation protocol.

Creation of the Cockpit Model

Sonic digitization was used to collect crew station geometry information. This technology uses the time taken for sound to be received from a sound source to measure distances. Software converts these distances into X, Y and Z coordinates. Periodic checks of the data during digitizing indicated that the points collected were within 0.5 cm of their true position in the crew station [30].

The sonic digitization data were interpreted using the Automated Model Generation System (AMGENS). [31]. AMGENS is a series of computer programs written by DCIEM to convert the 3-dimensional coordinate data into a format that can be interpreted by SAMMIE. Within SAMMIE, AMGENS uses standard naming conventions to create a hierarchical, colour-coded, 3-dimensional model that can be displayed graphically. Each crew station model generated using AMGENS was examined and edited interactively to ensure it was properly formated for execution of the evaluation protocol.

Crew station seat and pedal adjustment stepsizes were set at 2 cm. For the CT133 Silver Star, this meant that 56 configurations (i.e., 7 seat positions × 8 rudder pedal positions) would be tested. For the CH136 Kiowa, which has a non-adjustable seat, this meant that 7 configurations (i.e., 1 seat position × 7 rotor pedal positions) would be tested.

Creation and Placement of the Manikin

A SAMMIE manikin was added to the crew station model with the aid of an interactive computer program. First, a manikin having prescribed body dimensions and joint constraints was created. Calculations that used seat pan angle, seat back angle and assumptions for body enfleshment dictated the location of the manikin with respect to a standard seat reference point (SRP). The manikin's posture was manipulated so that the torso was parallel to the seat back, and the line of sight was horizontal. To optimize body clearance evaluations, entities representing body enfleshment and clothing assumptions were added to the manikin. The entities used to check clearance with the seat pan were narrow planar surfaces running along the backs of the manikin's thighs. Entities used to check clearance with the front instrument panel were cylinders of appropriate diameters (i.e., enfleshment plus clothing allowance) around each of the manikin's thighs and calves.

Ranges for adjusting the manikin's anthropometric dimensions were chosen to exceed values listed in the NASA Anthropometric Source Book [29]. Sitting height, eye height, acromion height, forward functional reach, buttock-knee length and knee height dimensions were represented to a resolution of 1 cm. The resolution for biacromial breadth gave representation of a *small*, *medium* and *large* value on that dimension.

Execution of the Evaluation Protocol

Aircrew/Cockpit Compatibility Evaluation Protocol (ACCEP) is a set of SAMMIE computer programs that implement the evaluation strategy [32]. It manipulates aircrew anthropometry and crew station geometry parameters in order (a) to reveal and identify physical conflicts in reach, vision and body clearance requirements, and (b) to determine multi-dimensional envelopes that express the physical size limits for current CF crew stations.

For each of the CT133 and CH136 crew stations, ACCEP was run within a SAMMIE software environment on a Prime 2350 mini-computer. The output obtained using ACCEP was formated in a data base. Three types of assessment were performed; individual fit, percentage accommodation for males and females, and comparison of accommodation in the aircraft with satisfaction of CF aircrew selection criteria.

4. RESULTS

The results from ACCEP contain all possible anthropometric combinations that will fit each pilot crew station — within the described resolution limits. It is a relatively simple procedure to search this data set to determine whether a given individual has the necessary anthropometric dimensions to fit a particular crew station. A population of such individuals (measured on the appropriate anthropometry dimensions) can also be used to yield estimates of percentage accommodation. Submitting the same population to current selection standards also yields accommodation results with which comparisons can be made. For the purposes of this paper, anthropometry data for males and females were obtained from the 1967 survey of United States Air Force (USAF) male flying personnel (n=2420) and the 1968 survey of USAF women (n=1905) [33,34].

Accommodation assessments were based on aircraft requirements for head clearance, vision, leg reach and clearance and, in the case of the CT133, ejection clearance. Unless otherwise stated, arm reach requirements were not considered because of the difficulty in choosing the most *important* set of arm reach targets for a crew station. Given that CF selection standards do not consider requirements for arm reach, valuable comparisons between aircraft-imposed limitations and standards-imposed rejections could be made without consideration of this criterion.

Table 1 lists the anthropometric criteria that must be satisfied for current CF aircrew selection. Applying these criteria to the male and female USAF populations yielded acceptance figures of 94% and 36%, respectively. The high acceptance value for males is due to similarities in CF and USAF aircrew selection standards. It is anticipated that the acceptance would be lower for an unbiased male population (i.e., a population that was not pre-screened). The low acceptance value for females is understandable given the source of the CF selection criteria (i.e., originally derived from male aircrew data). Also, the female population surveyed did not undergo the same anthropometric screening as the male population, offering a partial account for the high rejection rate of the females compared to the males.

Figure 4a illustrates the percentage accommodation in each aircraft for the combined populations (males and females) as determined by the ACCEP evaluation. Seventy-five percent satisfy compatibility requirements for the CT133 jet aircraft (i.e., are able to fit in at least one seat/pedal configuration). The CH136 helicopter

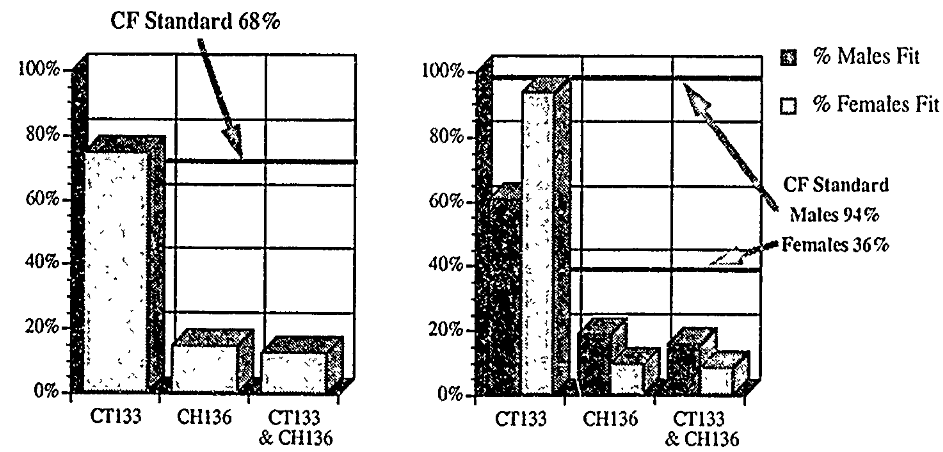


Figure 4a: combined populations (males and females)

Figure 4b: males vs females

Figure 4. Percentage accomodation in each aircraft for the combined populations and by gender.

is considerably more restrictive, resulting in only 15% accommodation. The percentage of the combined populations able to fit both aircraft is 13%. Notice that acceptance according to CF selection standards remains constant across aircraft, at 68%.

Figure 4b presents the same percentage accommodation data, grouped by gender. Clear differences exist between males and females for the two aircraft. A smaller percentage of males (61%) than females (94%) can fit in the CT133. For the CH136, the reverse trend is observed (males 19%, females 10%). The percentages of the male and female populations able to fit both aircraft are 16% and 9%, respectively. more males (16%) Again, the CF selection standards bear little relationship to aircraft type or to gender differences.

Figures 5a and 5b illustrate reasons behind the gender differences observed in Figure 4b. Accommodation percentages for males and for females are plotted to show the additive effects of the compatibility criteria. For the CT133 (Figure 5a), differences between males and females are largely due to head clearance requirements. Females, being shorter than males, experience fewer problems hitting the canopy (99% fit for females versus 66% fit for males). Females also experience fewer problems hitting the knees on ejection. For the CH136 (Figure 5b), incompatibility problems are different. Again, females do better than males for head clearance (99% fit versus 54% fit). However, females undergo a much larger additional rejection (89%) than do males (35%) due to leg accommodation problems — relatively long legs are needed to reach the rotor pedals in the CH136. Vision is not a problem in either the CT133 or CH136 aircraft because of the large cockpit surfaces devoted to windows. These results contrast strongly with accommodations according to CF selection criteria. The CF criteria reject a significant number of females on the basis of sitting height (60%), yet reject relatively few on the basis of leg length measures (26%).

Results obtained for the CT133 and the CH136 also illustrate gender differences in accommodation among upper- and lower-body dimensions respectively. For the CT133, Figures 6a to 6d show the bivariate frequency distribution for sitting height and forward functional arm reach for the combined population (males and females). The associated bar graphs represent the percentages of males and females who meet specified accommodation requirements.

Figure 6a shows the combined population (males and females) with no restrictions imposed — hence both males and females show accommodation of 100%. Figure 6b illustrates the effect of requiring the sample to satisfy head clearance requirements for the CT133. Lightly shaded areas represent individuals who are able to fit the CT133 whereas darkly shaded areas represent individuals who are not. The bar graph demonstrates that males are more affected than females (as was seen in Figure 5a). Figure 6c shows the accommodation/rejection results that combine head clearance and the minimum arm reach needed to reach a single target in the CT133 — the compass switch (the compass switch was chosen for illustration purposes because approximately 50% of the combined population could reach it). As can be seen from Figure 6c, sitting heights and arm lengths necessary to reach the compass switch are not linearly related. Also, females are much more affected by this restriction than males (a drop of accommodation by 45% for females versus 10% for males). Again, the higher rejection rate for females is due to the combined effects of females being smaller than males, and the pre-screening of the male population. Figure 6d represents the effect of the CF standard for minimum and maximum allowable sitting heights (recall that the standard does not give arm reach requirements). It is clear from this figure that the CF selection standards are too simplistic. Although approximately the same percentage of females are rejected as shown in Figure 6c (ACCEP criteria for head clearance and arm reach), the reasons for rejection are inappropriate. Females are rejected on the basis of seated height whereas the accommodation problem is based on functional arm reach.

Results for the CH136 are used to illustrate lower-body dimension interactions. Figures 7a to 7c show the bivariate frequency distribution for buttock-knee and popliteal height for the combined populations. The associated bar graphs represent the percentages of males and females who meet requirements for leg reach and clearance. Figure 7a shows the entire population with no restrictions imposed — as for Figure 6a, both males and females show 100% accommodation. Figure 7b shows the combined effects of leg reach and leg clearance on lower-body accommodation. The lightly shaded areas represent individuals who fit in the crew station. Darkly shaded areas indicate individuals who have reach and/or clearance problems. The bar graph shows the dramatic effect that leg accommodation requirements have on females (89% rejection), males are affected to a lesser degree (51% rejection) (recall Figure 5b). Figure 7C shows the portion of the population affected by CF selection limits for buttock-knee length and buttock-heel length. The disparity between results shown in Figures 7b and 7c is a clear indication that, for the CH136, the CF selection criteria are too liberal.

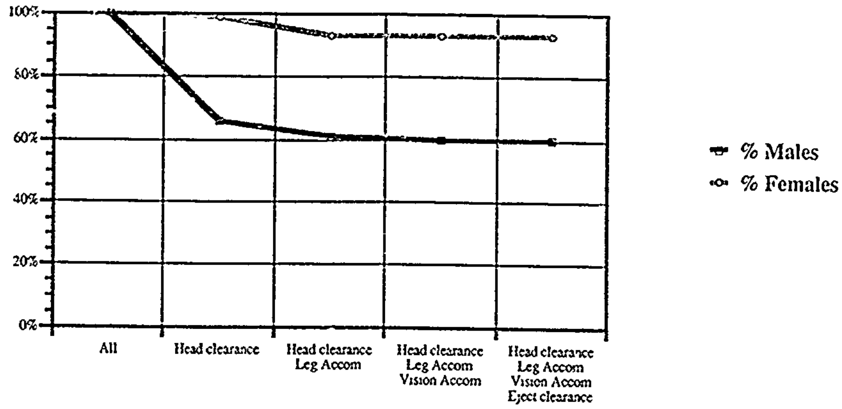


Figure 5a. Additive effects of compatibility criteria on percentage accomodation for the CT133.

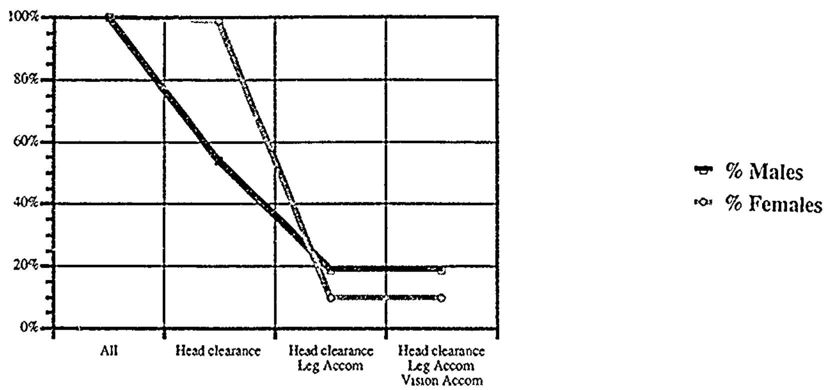


Figure 5b. Additive effects of compatibility criteria on percentage accomodation for the CH136.

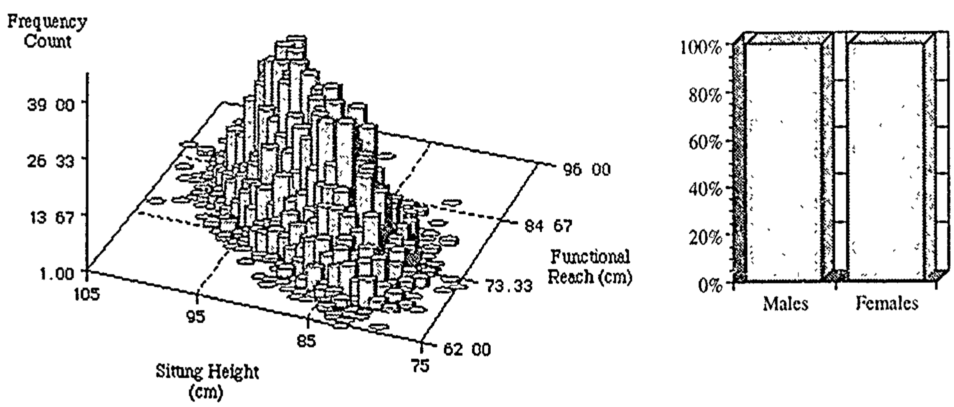


Figure 6a. No restrictions imposed.

Figure 6a. Frequency distribution for sitting height and forward functional reach, indicating regions of acceptance and rejection according to specified accommodation requirements for the CT133. Bar graphs indicate percentages of males and females meeting acceptance.

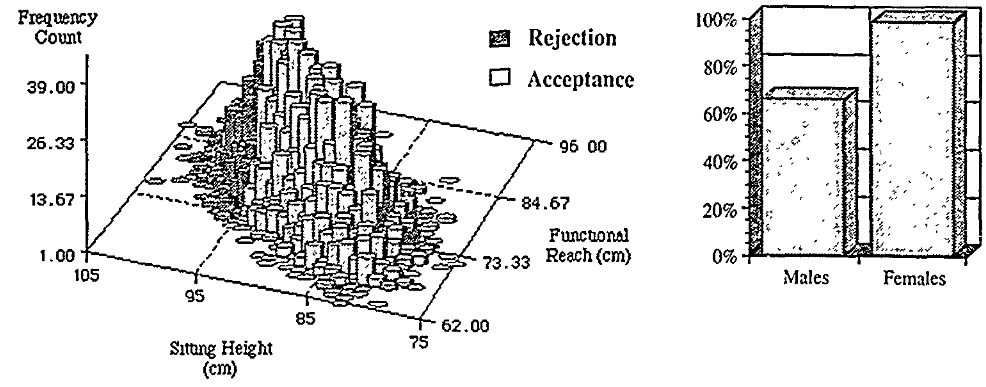


Figure 6b. ACCEP head clearance requirement.

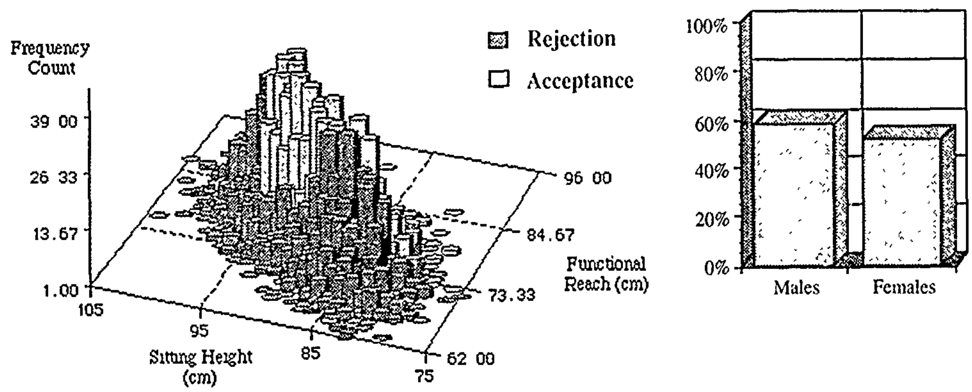


Figure 6c. ACCEP head clearance and minimum functional arm reach requirements.

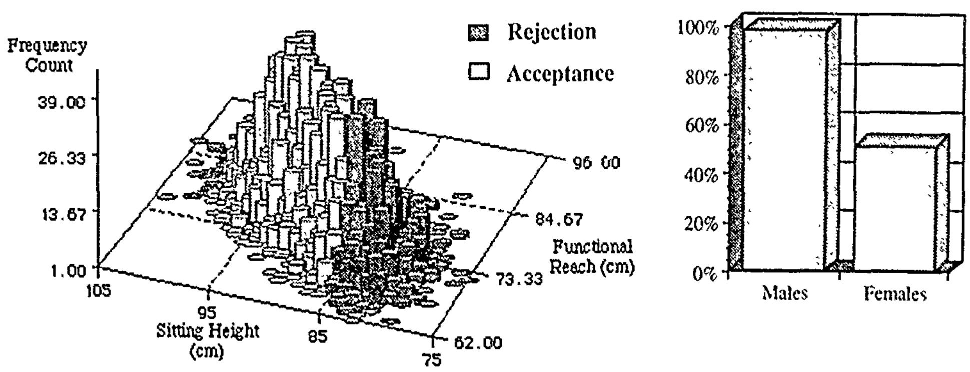


Figure 6d. CF standard for sitting height.

Figures 6b to 6d. Frequency distribution for sitting height and forward functional reach, indicating regions of acceptance and rejection according to specified accommodation requirements for the CT133. Bar graphs indicate percentages of males and females meeting acceptance.

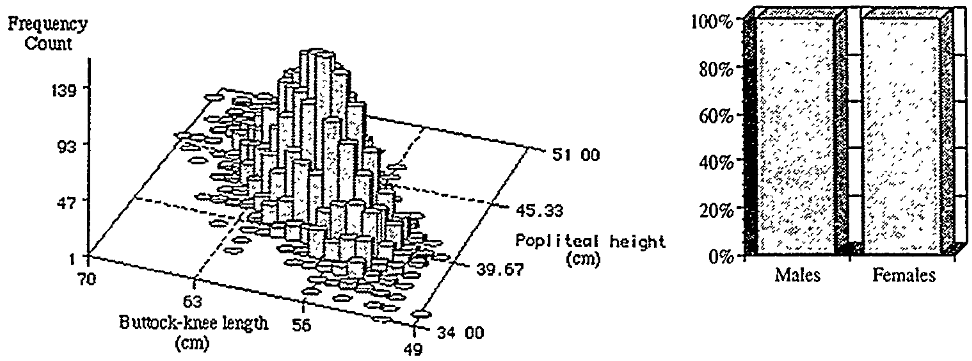


Figure 7a. No restrictions imposed.

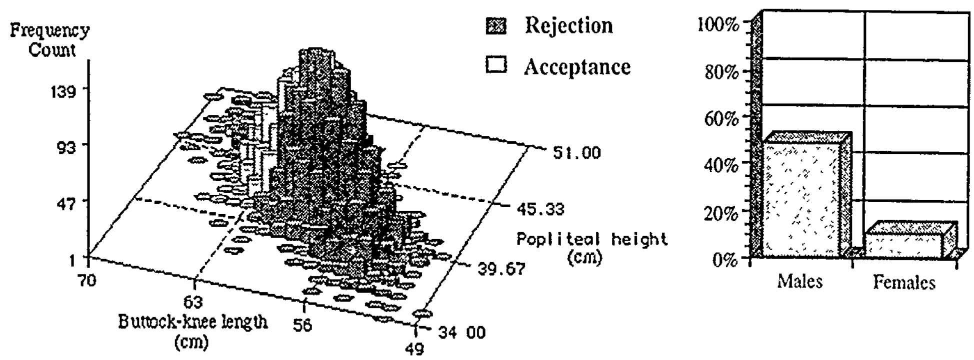


Figure 7b. ACCEP leg reach and leg clearance requirements.

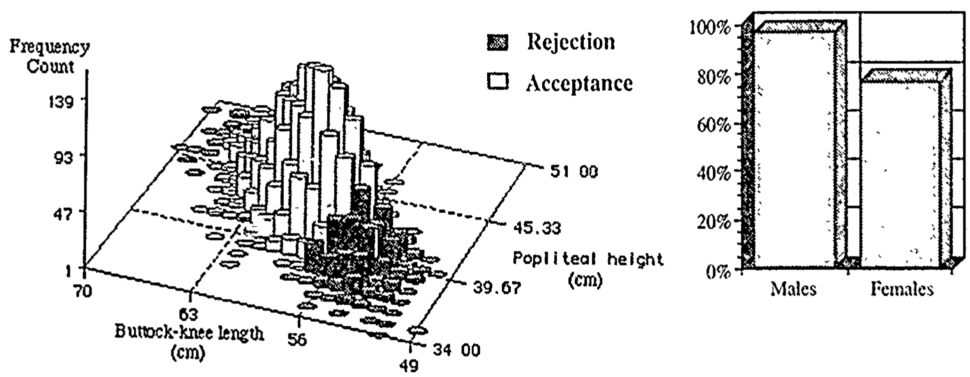


Figure 7c. CF standards for buttock-knee length and buttock-heel length.

Figure 7. Frequency distribution for buttock-knee length and popliteal height, indicating regions of acceptance and rejection according to specified accommodation requirements for the CH136. Bar graphs indicate percentages of males and females meeting acceptance.

5. DISCUSSION

This paper discusses a study done to determine the anthropometric limitations imposed by the pilot crew stations of the CT133 utility jet and CH136 light observation helicopter. Results of the study offer interesting observations on the accommodation of females in each of the aircraft. To complete the study, ACCEP was employed to manipulate anthropometry and crew station geometry parameters in a computer-modelling environment. Physical conflicts in reach, vision and body clearance were identified and multi-dimensional envelopes expressing crew station limitations in terms of acceptable anthropometric combinations were determined. Data obtained were used to assess individual and percentage accommodation of males and females in each of the two crew stations. Criteria for compatibility included head clearance, vision, leg reach and leg clearance. Although arm reach requirement data were available, they were not considered because of the difficulty in choosing comparable sets of reach targets for the crew stations. This omission must be appreciated in interpreting the results, as arm reach requirements could have significant influence on individual and population accommodation outcomes.

It is clear from the results that the anthropometric limitations imposed by the CT133 and CH136 pilot crew stations differ. This is evident from the percentage accommodation results obtained. Whereas both aircraft have similar seated height requirements, the CH136 imposes extremely restrictive leg length requirements. These results are not surprising in that the CT133 and CH136 are known to pose physical compatibility problems for both large and small individuals. What is surprising is the number of individuals who are incompatible with these aircraft (25% rejection for the CT133, 85% rejection for the CH136). These rejection figures reflect incompatibilities of larger individuals with the CT133 and incompatibilities of smaller individuals with the CH136. A point of interest is that anthropometric accommodation in the CH136 is satisfied by a sub-set of the anthropometric space satisfying CT133 accommodation. This is shown by the very small difference (2%) in percentage accommodation for both aircraft versus the CH136 alone. Hence, the combined influences of the aircraft on percentage accommodation are such that those who fit in the CH136 are compatible with the CT133. The opposite is not true, however; many who fit in the CT133 do not fit in the CH136.

Accommodation is influenced by the relative size of the population as well as the crew station's geometry. Results of this study indicate that accommodation differs between males and females in each of the CT133 and CH136 aircraft. In the case of the CT133, head clearance poses considerable restriction for males and almost none for females. Other compatibility criteria have very little influence on either gender. Overall, female percentage accommodation is extremely high (94%) whereas male percentage accommodation is somewhat lower (61%). This is surprising given that the CT133 was designed for a male population. It is also interesting to note that both populations are best accommodated with the crew seat in its full-down position, even though the CT133 offers seat adjustability. In the case of the CH136, sitting height again poses a much greater restriction for males than for females. Leg accommodation requirements restrict both genders, but have much greater impact on female compatibility. Although accommodation of each of the male and female populations is very low (19% and 10% respectively) males have a higher percentage accommodation for that aircraft. Across aircraft, females are generally rejected on the basis of leg length measures while males are generally rejected on the basis of sitting height measures. The net effect is that the CT133 is more restrictive to the male population and the CH136 is more restrictive to the female population.

Individual and population accommodation assessments for each of the CT133 and CH136 offered a basis for comparing fit in the aircraft with satisfaction of the CF aircrew selection criteria. Results of the comparisons indicate that the CF standards are too simplistic. For one, they do not account for interaction effects such as those seen for sitting height and arm reach in the CT133, and leg reach and clearance in the CH136. Given that those evaluations were intended to provide simple examples of upper-body and lower-body interactions in isolation, it can be anticipated that the interactions required for *total-body* compatibility are still more complex. Interaction effects cannot be expressed using simple minimum and maximum values for individual anthropometic dimensions. These results also suggest that the standards must include a lower leg length measure (e.g., sitting knee height) to account for interactions with the upper leg that effect leg accommodation. The standards should also include arm reach considerations although specific recommendations must be based on further study of interaction effects of upper-body dimensions.

Perhaps the most important implication from the study is that the selection standards are biased against females (and perhaps small males). Results obtained for the CH136 provide evidence of this problem. For that aircraft, female percentage accommodation for upper-body requirements resembles percentage accommodation using the CF selection standards. Unfortunately, the two percentages represent different portions of the female population (aircraft accommodation is based on functional arm reach while satisfaction of the CF standards is based on sitting height). This contrasts with evidence of a bias in favour of large males who have head clearance problems in the CT133 yet satisfy the CF standard for sitting height. While the CF selection criteria are too restrictive for women with respect to fit in the CT133, they are too liberal with respect to fit in the CH136. However, extremely low percentages of accommodation for both males and females in the CH136 suggest that the CH136 should be treated specially: either the crew station should be modified to better accommodate aircrew or it should have its own standards for selection of aircrew. Ultimately, CF selection standards that indicate biases for or against either gender must be substantiated on the basis of limitations imposed by CF aircraft.

Through this study, the utility of employing ACCEP to map the relationship between anthropometry and crew station geometry has been demonstrated. ACCEP provides a data set within which individual anthropometric profiles can be searched against successful anthropometry combinations to fit particular aircraft crew stations. In its simple form, the ACCEP data set shows promise as a tool for selecting or rejecting individual aircrew candidates. For population evaluations, it can also be used to yield cumulative percentage accommodation results according to specified compatibility criteria. This use of the data set offers an informative means to identify anthropometric limitations that distinguish one aircraft from another. In this way, ACCEP appears to be a promising tool for looking at broader selection issues (such as pilot career planning) based on evaluations of a fleet of aircraft.

The evaluation process does not end here. Results of ACCEP depend upon mathematical assumptions that are only simplifications and approximations of reality — the computer models are only as good as the input data and modelling assumptions used for their creation and manipulation [35]. Therefore, compatibility tests using live subjects must be performed to validate anthopometry/crew station relationships before ACCEP results are implemented in aircrew selection or aircraft assignment policies.

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PROBLEMES POSES PAR L'ADAPTATION DES EQUIPEMENTS DE PROTECTION PHYSIOLOGIQUE AUX PILOTES FEMININS D'AVIONS DE COMBAT.

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RESUME

Dans un futur plus ou moins lointain, il est possible que des femmes soient amenées à piloter des avions de combat. Ceci pose le problème de l'adaptation des équipements de protection physiologique à ces pilotes féminins. A partir des données bibliographiques et des bases théoriques concernant le fonctionnement de ces équipements les problèmes morphologiques et physiologiques spécifiquement féminins sont analysés. Les solutions envisageables sont présentées dans le domaine de la protection contre les effets physiologiques des accélérations, l'immersion et la diminution de la contrainte thermique liée au port de la combinaison NBC. Des questions restent posées et demanderont des expérimentations ultérieures en Laboratoire.

ABSTRACT

Female pilots would have to pilot fighter in the future. The problem of adaptation for flight equipment is induced by this new population of pilots. The specific female equipment functionning is studied from theorical basis and from the litterature. Operational solutions are presented for high G protection, thermal stress induced by C.W. flightequipment. Some questions are, today, without response and require further laboratory experiments.

INTRODUCTION

Si dans certains pays occidentaux et en particulier en Amérique du Nord les femmes remplissent certaines fonctions sur des avions à hautes performances, l'Armée de l'Air Française n'est pas encore parvenue à ce stade. En effet si l'on trouve des pilotes féminins commandant de bord sur avions de transport et sur hélicoptères, aucune femme aujourd'hui n'exerce de fonctions sur avions de chasse.

Cependant la féminisation croissante des effectifs de l'Armée de l'Air laisse à penser qu'à plus ou moins brève échéance des pilotes féminins pourront être amenés à piloter des avions hautes performances. De ce fait, ces femmes se trouveront exposées aux mêmes contraintes physiologiques que leurs homologues masculins. La protection contre ces agressions est classiquement assurée par un certain nombre d'équipements individuels, dont l'ajustement précis est une condition nécessaire à leur pleine efficacité.

Si la tolérance volontaire des femmes contre certaines agressions aéronautiques n'est pas a priori différente de celle des hommes, les équipements de protection visant à augmenter cette tolérance ne sont peut-être pas directement utilisables du fait des différences morphologiques et physiologiques existant entre les deux sexes.

Nous nous proposons donc, au cours de cet exposé non exhaustif, de présenter sur le plan théorique les problèmes susceptibles de se poser dans l'adaptation des équipements de protection physiologique couramment utilisés dans l'Armée de l'Air Française. Nous exposerons également les solutions envisageables compte tenu de notre expérience.

I. - Différences morphologiques

Les différences de taille et de morphologie entre la population masculine et la population féminine apparaissent évidentes d'emblée. Au cours de cette réunion une étude plus complète sur les normes anthropomorphiques et la sélection des personnels navigants féminins français a déjà été présentée. Nous ne soulignerons donc que quelques éléments paraissant importants dans la conception et la réalisation des équipements de protection physiologique.

Les tailles des équipements sont prévues pour couvrir une population de pilotes comprise entre le 3ème et le 95ème percentile. Le tableau suivant, reprend des données de la bibliographie et regroupe les principales valeurs caractéristiques chez l'homme et chez la femme au 5ème et au 95ème percentile.

	5 %		95 %	
	Homme	Femme	Homme	Femme
Poids (kg)	60,4	46,4	96	76,5
Stature (m)	1,64	1,52	1,87	1,72
Périmètre thoracique (m)	0,875	0,782	1,084	1,073
Largeur épaules (m)	0,432	0,358	0,526	0,458

L'étude de ces données permet immédiatement de noter que les valeurs relevées dans l'échantillon minimum correspondant à 5 %, nécessitera la création de tailles supplémentaires pour couvrir l'ensemble de la population des pilotes. On observe en effet qu'au 5° percentile la différence de stature est de l'ordre de 10 cms entre l'homme et la femme. Ces modifications toucheront aussi bien les équipements de vol classiques (combinaison et sous vêtements) que les équipements techniques (pantalon anti-G, combinaison d'immersion, etc...). De plus et sans entrer dans les détails, il est probable que pour un certain nombre d'équipements à ces modifications de taille viendront s'ajouter des modifications du patronnage particulièrement en ce qui concerne le buste.

II. - Equipements techniques

Nous éliminerons volontairement de cette discussion les problèmes pouvant se poser à la suite de l'utilisation d'équipements de protection physiologiques chez une femme au début d'une grossesse. Cette situation devrait être évitée par l'adoption de dispositions réglementaires à définir précisément. En tout état de cause, il paraît difficile dans l'état actuel des connaissances de prévoir les conséquences sur la grossesse d'une exposition aux contraintes aéronautiques, telles que les accélérations ou d'une utilisation d'équipements de protection physiologique.

Les remarques précédentes ont un caractère général mais un certain nombre de questions particulières sont à envisager pour prendre en compte des problèmes physiologiques spécifiques aux agressions aéronautiques. Nous insisterons particulièrement sur les équipements de protection contre les accélérations et ceux modifiant les échanges thermiques de l'homme avec son environnement.

2.1. - Protection anti-G

2.1.1. - Pantalon anti-G

Le pilotage des avions de combat expose l'équipage à des accélérations. La réalisation d'avions de plus en plus performants entraîne des accélérations plus intenses et plus rapidement établies. Les limites de tolérance de l'organisme humain sont largement dépassées et imposent donc le port d'équipements individuels de protection contre les effets physiologiques des accélérations.

Les mécanismes d'action de ces équipements sont basés sur la théorie physiopathologique la plus couramment admise par la communauté scientifique pour expliquer les effets physiologiques observés. Cette théorie est hémodynamique et admet que sous l'effet des forces d'inertie liées aux accélérations + Gz, le sang s'accumule dans les territoires infracardiaques, réalisant une véritable spoliation sanguine dans les territoires supracardiaques, ce qui diminue le remplissage cardiaque Le résultat en est une baisse du débit cardiaque et de la pression artérielle et ce en dépit des réactions vaso-constrictrices. Cette hypotension associée à l'augmentation de la pression hydrostatique dans la colonne sanguine coeur-cerveau, entraîne une diminution voire un arrêt de la perfusion cérébrale d'où survenue du voile noir et secondairement perte de connaissance.

La protection physiologique contre les accélérations fait classiquement appel au pantalon anti-G et à l'inclinaison du siège. Si ce second moyen paraît devoir apporter la même protection quel que soit le sexe du pilote, il est possible que, compte tenu des différences physiologiques entre les sexes, l'efficacité du pantalon anti G soit modifiée.

S'agissant de l'accumulation du sang dans les membres inférieurs on peut s'interroger sur l'existence d'une éventuelle différence de compliance veineuse entre les deux sexes. Une augmentation de cette compliance serait susceptible de majorer le stockage sanguin dans la partie inférieure du corps. Si une telle différence peut être mise en évidence, l'utilisation de pantalons anti-G, possédant une loi de gonflage différence ou la conception d'un équipement à poche unique et complète (full coverage), déjà envisagée pour les pilotes masculins, pourrait s'avérer indispensable.

Il s'avère en fait que des études dans ce sens ont été menées sur des femmes en utilisant une technique de Low Body Negative Pressure. Cette expérimentation réalisée par FREY et Coll. en 1986 tend à réfuter l'existence d'une telle différence. Il apparaît tout au plus que les adaptations cardio-vasculaires à une telle agression sont différentes chez la femme et chez l'homme. Il est logique de ce fait de réfuter l'hypothèse d'un stockage veineux plus important chez la femme au cours de l'exposition aux accélérations.

La réduction de la perfusion cérébrale est, nous l'avons vu, liée à l'augmentation de la pression hydrostatique dans la colonne sanguine coeur-cerveau. La taille moyenne des femmes étant inférieure à celle des hommes, cette distance est plus petite et ceci apparaît comme un facteur favorisant la tolérance aux accélérations. Ce fait a été démontré expérimentalement par GILLINGHAM et Coll. (1986).

Outre les problèmes de compliance veineuse, on peut s'interroger sur l'efficacité de cet équipement en fonction de son plus ou moins bon ajustement. La vérification de l'adéquation entre la morphologie féminine d'une part et le pantalon anti-G d'autre part apparaît indispensable. En fonction des résultats de cette étude des modifications de taille et de découpe seront peut être à envisager. Cependant il est à noter que le pantalon actuellement en service dans l'Armée de l'Air, dispose de nombreux réglages permettant de personnaliser l'équipement ce qui devrait autoriser les adaptations nécessaires à la morphologie féminine.

Sur le plan du confort associé au fonctionnement de cet équipement, les différences entre les anatomies masculines et féminines pourraient faire craindre des problèmes spécifiques, en particulier au niveau de l'appareil génito-urinaire. Lors d'une expérimentation menée par GILLINGHAM et coll. à l'USAF SAM en 1986, cet aspect a été abordé grâce à un questionnaire proposé aux sujets féminins à l'issue de tests en centrifugeuse. Sur 24 sujets testés avec un pantalon anti-G aucun n'a signalé d'inconfort particulier. Tout au plus peut-on observer que deux femmes ont présenté une incontinence urinaire liée, semble-t'il au gonflement de la poche abdominale sur une vessie en réplétion.

Au total s'agissant de l'utilisation du pantalon anti-G chez des pilotes féminins les expérimentations menées permettent de penser qu'elle n'entraîne pas de problème physiologique spécifique. La seule modification à entreprendre semble porter sur une adaptation des tailles de cet équipement.

2.1.2. - Surpression respiratoire

L'augmentation des niveaux d'accélération rencontrés en aéronautique militaire amène à envisager l'utilisation de nouvelles techniques de protection physiologique contre cette agression. Parmi celles-ci la surpression respiratoire est en cours d'évaluation en France et devrait être utilisée très prochainement dans de nombreuses Armées de l'Air Occidentales. Outre les problèmes de mécanique ventilatoire que pose cette technique l'application d'une contre pression thoracique importante peut entrainer des troubles spécifiques liés à l'anatomie féminine.

L'équipement utilisé en France a été développé afin d'assurer la protection respiratoire des pilotes contre le risque de décompression cabine en haute altitude. Cet ensemble ou VHA 90 comprend outre un équipement de tête une veste de surpression munie d'une vessie couvrant la totalité de la face antérieure du thorax. Cette vessie est destinée à assurer une contrepression égale à la valeur de la surpression respiratoire et peut atteindre une valeur de 9 kPa.

On peut s'interroger sur le niveau de pression acceptable par les femmes, compte tenu de la présence des glandes mammaires et sur l'éventuelle nécessité de modifier la découpe de la veste de surpression ou sa conception en élargissant la surface d'application de la contre-pression.

Il est impossible à l'heure actuelle de prévoir les conséquences à long terme sur la physiologie mammaire d'agressions répétées au cours de la carrière d'un pilote. Ceci apparaît d'autant plus important qu'a priori cet équipement s'adresse à des femmes jeunes, donc en âge de procréer, et par la même susceptibles d'allaiter. Les données de la bibliographie et notre expérience sont insuffisantes, voire inexistantes pour permettre de répondre à ces questions.

En dernier lieu, il est difficile de ne pas envisager les conséquences esthétiques à long terme d'une exposition répétée aux accélérations et une utilisation répétée de la surpresion respiratoire assistée. Si la prévention peut apparaître difficile, une information des personnels devra être entreprise.

En tout état de cause, une modification de la découpe de la poche thoracique et du gilet de surpression sont à envisager afin de préserver l'efficacité de la surpression respiratoire. Une meilleure répartition obtenue par une découpe plus adaptée à la morphologie féminine améliorerait sans doute le confort. Une autre solution consisterait à une extension dorsale de la poche thoracique permettant de répartir plus uniformément la contre pression sur le thorax. Cette solution, bien que séduisante, risquerait d'entraîner un inconfort vis-à-vis du dossier du siège.

2.1.3. - Multifonctions

Intégrant entre autres la surpression respiratoire et le pantalon anti-G, le vêtement multifonctions en cours d'évaluation pose les mêmes problèmes que ceux envisagés précédemment pour chacun de ces équipements. Si ce vêtement multifonctions doit être utilisé dans l'avenir, une personnalisation de l'équipement apparait souhaitable afin d'assurer une efficacité maximale.

2.2. - Combinaison d'immersion

La combinaison d'immersion, fréquemment employée dans l'Aéronavale et lors des survols maritimes par temps froid par les pilotes de l'Armée de l'Air, doit assurer la protection contre le refroidissement en cas d'immersion en eau froide. Son efficacité est liée à son étanchéïté, l'isolement thermique étant assuré par les sous-vêtements. La protection apportée n'est pas a priori différente chez l'homme et chez la femme.

Le problème principal posé par cet équipement concerne le port prolongé au cours des vols longue durée. La disposition de la braguette en position horizontale est déjà plus ou moins adaptée aux pilotes masculins mais apparaît tout à fait inappropriée voire inutile pour les pilotes féminins. Des modifications de la tenue dans sa définition actuelle apparaissent délicates voire impossibles. Des solutions de remplacement devront impérativement être prévues afin d'assurer le confort des personnels féminins et ce quelles que soient leurs conditions d'emploi.

2.3. - Autres équipements de protection physiologique

Un dernier point particulier mérite d'être examiné. Il s'agit de l'utilisation d'une climatisation individuelle pouvant être associée à l'équipement N.B.C.

Le port de la combinaison NBC entraîne une contrainte thermique parfois importante. Le stockage thermique en résultant peut nuire à l'efficacité opérationnelle des équipages. Les moyens de prévenir cette contrainte font appel à une climatisation individuelle. Deux techniques sont utilisables, soit une circulation au contact du corps de liquide réfrigéré, soit une ventilation forcée avec de l'air réfrigéré.

La première technique, circulation de liquide, diminue la contrainte thermique en augmentant les échanges par conduction entre la peau et le milieu extérieur. Cette méthode nécessite donc un contact étroit entre la peau et le réseau canalaire où circule le liquide réfrigérant. Dans sa définition actuelle le système est bien adapté à la morphologie masculine mais des adaptations de la découpe seront à prévoir pour les femmes si ce type de gilet devait être utilisé dans l'avenir à bord des avions.

En revanche, l'utilisation d'une ventilation corporelle qui augmente les échanges par convection ne semble pas devoir à priori donner des résultats différents chez l'homme et chez la femme.

En conclusion, nous avons envisagé au cours de cet exposé, les problèmes pouvant résulter de l'adaptation des équipements de protection physiologique aux pilotes féminins d'avions de combat. En dépit de notre modeste expérience les données bibliographiques et les bases théoriques permettent de penser que dans l'ensemble les solutions seront faciles à mettre en oeuvre. Il n'en reste pas moins que dans l'état actuel de nos connaissances, un certain nombre de questions restent à résoudre et devront faire l'objet d'expérimentations en laboratoire. Ceci permettra d'apporter des solutions techniques ou réglementaires aux problèmes spécifiques, tant morphologiques que physiologiques, des pilotes féminins.

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SOME EQUIPMENT PROBLEMS ASSOCIATED WITH THE INTRODUCTION OF FEMALE AIRCREW INTO THE ROYAL AIR FORCE

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SUMMARY

Female aircrew have been employed for several years as Air Loadmasters operating on VC10 transport aircraft. When it was required that all transport aircrew be issued with Nuclear, Biological and Chemical (NBC) protective equipment an anthropometry and sizing exercise was conducted with 21 randomly selected female Loadmasters. This paper describes the problems experienced and relates them to the anthropometry data. Mention is also made of the anticipated problems with the Royal Air Force's recent decision (1989) to train female Pilots and Navigators.

INTRODUCTION

Female aircrew have been employed in the Royal Air Force (RAF) for over a decade albeit in one specific role. There are some 30 female Air Loadmasters (ALM) operating primarily on VC10 aircraft. A small number have moved on to Hercules operations. Initially they were not issued with functional aircrew clothing assemblies. However, in the early 1980s, it was decided that all transport aircrew were to be issued with Nuclear, Biological and Chemical (NBC) protective equipment.

Candidates for Air Loadmasters must be between 1575 mm and 1905 mm tall and those between 1575 mm and 1600 mm tall must achieve a vertical functional reach of at least 1975 mm. Pilots and Navigators are subject to anthropometric limitations in four key dimensions which do not include stature. However the minimum stature for which one piece aircrew coveralls are designed is 1651 mm. It was therefore not unexpected to find problems when fitting these female ALMs with equipment designed for the male aircrew proportion. An anthropometry and sizing exercise was conducted using 21 randomly selected female ALMs.

The NBC equipment assembly, the fit of which was assessed, comprised the Aircrew Respirator NBC No 5 (AR5), Type G fabric Helmet, NBC Coverall Mk 1, Aircrew Coveralls Mk 14, NBC Gloves, Cape Leather Gloves, NBC Socks and Aircrew Boots. This paper describes the standards of fit achieved and relates them to the anthropometry data. Details of certain key parameters are given for each of the 21 females in Table 1. Each clothing item is discussed in turn in the following paragraphs.

FIT OF INDIVIDUAL GARMENTS

Coveralls, Aircrew Mk 14

The fit of the Mk 14 coveralls, the outer garment, was generally good. Although the majority of the females were shorter in stature than the nominal lower limit of the size roll, the size 1 garment proved an acceptable fit. Only 7 subjects required larger sizes, one of which was a size 9, the largest available. For six subjects the leg length was excessive. The arm length was considered to be too great on only one subject. In order to avoid costly special made to measure garments, the legs of the coveralls, are to be shortened at unit level. In addition, the lower leg pockets are not used by the Loadmaster and they can be removed. However, when the excess length on the leg is cut off it may be necessary to procure special sliding fasteners.

Coveralls, NBC Mk 1

This garment, worn beneath the Mk 14 Aircrew Coverall, is sized to the standard size roll for one piece garments. Again all the WRAF Loadmasters were satisfactorily fitted with a stock size NBC coverall. Minor problems were experienced concerning the amount of turn-back on the legs (maximum of 180 mm) and on the arms (maximum of 130 mm). Some discomfort was experienced due perhaps to the adjustment buckle becoming exposed. It was recommended that, at least for peacetime training, the excess material on the sleeves and legs be cut off and a stitch inserted in the seam of the material to avoid fraying.

Socks, NBC

Prototype socks in sizes smaller than the standard minimum size 5 were produced for the study. Of the 21 subjects nine required a size 4 sock and two required a size 3. Again this relates to their anthropometry - 9 had foot lengths below the male 1st percentile value. Items of this nature are easy to manufacture in smaller sizes relatively quickly and inexpensively.

Boots, Aircrew

All females were fitted satisfactorily with aircrew boots over the NBC socks. However several individuals reported difficulty when donning the boots in getting their foot round the pass line. For non NBC use smaller sizes of aircrew boots than the current male range will be required.

Gloves, Cape Leather

Many of the WRAF Loadmasters would have been better fitted with smaller sizes to eliminate looseness of material on the hand and excess finger length. The largest hand circumference of the 21 female subjects was only equivalent to the 2nd percentile male value.

Gloves, NBC

In only five of the twenty-one individuals was the small size of gloves considered to be a good fit. A smaller size of NBC glove is necessary requiring a smaller hand former to be developed.

AR5/Type G Helmet Assembly

Of the 21 female Loadmasters assessed a satisfactory fit of the AR5 assembly was obtained in only 3 individuals. The standard of fit was improved in a few instances when a development small butyl cowl AR5 was used. The smallest type G helmet (size 1) was too large for the vast majority of the subjects so that it was impossible to position the faceplate of the respirator correctly in relation to the face. It is clear that some modification of the type G helmet both in size and in the position of the press studs for the attachment of the mask suspension hooks is required. In one or two cases the small size of the mask of the AR5 was too long on the face making it impossible to obtain a mask seal. The AR5/type G helmet combination, in several cases, imposed a serious restriction of visual fields.

In 14 of the 21 individuals examined the neck seal exhibited an unacceptable leak. Air escaping through the neck seal may not only reduce the distribution of air flow over the internal surface of the visual area of the respirator but the level of protection against NBC warfare agents will be seriously impaired in the event of a failure of the blown air supply. In order to achieve a satisfactory neck seal for female personnel a new seal with the circumference reduced by at least 25 mm will be required. Only 1 of the 21 female subjects had a neck circumference greater than the male 5th percentile value.

Only 8 of the aircrew could achieve satisfactory occlusion of the nostrils with the standard nose occlusion device. In 10 instances however, modifications introducing heat shrink sleeving over the rollers had been carried out and in most of these it was possible for the aircrew to operate the nose occlusion device satisfactorily.

DISCUSSION

Whilst one or two items of aircrew equipment have been resized to fit female aircrew the majority of the failures of fit remain. The development and procurement processes are long and protracted particularly where expensive tooling is required. For small groups such as these female ALMs it is obviously more cost effective to modify existing equipment where possible.

The priority for provision of aircrew equipment assemblies for female aircrew changed in 1989 when it was decided to train women as Pilots and Navigators. The UK Research Establishments are now considering the fitting requirements of women when assessing new items of equipment. It is already evident that several of those female aircrew, currently under training, will require certain items of "special measure" functional clothing if they progress to ejection seat aircraft. Aircrew coveralls, immersion coveralls and G trousers are those garments which will require special attention. It is also expected that some women will not be fitted satisfactorily with existing protective helmets and oxygen masks. Until the changes or additions to current "male" size rolls are defined those individually made items could incur long delays due to the necessity to procure special length sliding fasteners, G-trouser bladders etc. Items such as helmets or boots cannot be made to order as no sufficiently small moulds or lasts exist. The situation does present a challenge to all concerned but no one can pretend that satisfactory size rolls of all aircrew equipment for both male and female aircrew will not be available for several years to come.

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TABLE 1 Anthropometry Details of WRAF Loadmasters

Subject	Stature		Chest Circ		Crotch Ht		Axilla-Waist Length	
	mm	%ile	mm	%ile	mm	%ile	mm	%ile
1	1565	<1(87mm)	924	20	734	<1(24mm)	422	3
2	1673	5	885	5	805	15	454	20
3	1650	2	922	20	796	10	459	25
4	1781	55	1107	99	853	50	479	55
5	1628	<1(10mm)	949	35	720	<1(38mm)	427	4
6	1653	2	891	5	755	<1(3mm)	440	10
7	1669	4	944	35	772	2	430	5
8	1653	2	915	15	768	2	464	35
9	1631	<1(7mm)	864	2	741	<1(17mm)	425	3
10	1648	2	1001	70	745	<1(13mm)	453	20
11	1602	<1(36mm)	917	15	747	<1(11mm)	404	<1(5mm)
12	1681	5	812	<1(33mm)	800	10	457	25
13	1649	2	874	4	765	2	483	60
14	1590	<1(48mm)	927	20	728	<1(30mm)	427	4
15	1636	<1(2mm)	835	<1(10mm)	795	10	483	60
16	1590	<1(48mm)	921	20	751	<1(7mm)	443	10
17	1576	<1(72mm)	826	<1(20mm)	747	<1(11mm)	423	3
18	1664	3	902	10	774	3	406	<1(3mm)
19	1664	3	854	2	785	5	484	60
20	1662	3	837	<1(9mm)	820	20	509	85
21	1645	2	930	25	764	2	479	55

TABLE 1 continued

Subject	Neck Circ		Head Circ		Foot Length		Hand Circ	
	mm	%ile	mm	%ile	mm	%ile	mm	%ile
1	320	<1(23mm)	546	1	234	<1(4mm)	181	<1(13mm)
2	331	<1(12mm)	560	10	242	2	159	<1(35mm)
3	350	3	555	5	233	<1(5mm)	193	<1(1mm)
4	405	90	545	<1(2mm)	264	50	195	1
5	352	3	549	2	239	1	196	2
6	344	1	556	5	243	3	184	<1(10mm)
7	354	5	555	5	239	1	182	<1(12mm)
8	335	<1(8mm)	551	3	249	10	187	<1(7mm)
9	328	<1(15mm)	544	<1(3mm)	229	<1(10mm)	170	<1(24mm)
10	341	<1(2mm)	558	10	239	1	183	<1(11mm)
11	345	1	561	15	230	<1(8mm)	176	<1(18mm)
12	313	<1(30mm)	533	<1(14mm)	240	1	176	<1(18mm)
13	327	<1(16mm)	544	<1(3mm)	237	<1(2mm)	173	<1(21mm)
14	345	1	572	40	227	<1(12mm)	179	<1(15mm)
15	330	<1(13mm)	545	<1(2mm)	233	<1(5mm)	190	<1(4mm)
16	345	1	595	90	241	2	183	<1(11mm)
17	322	<1(21mm)	549	2	232	<1(7mm)	176	<1(18mm)
18	341	<1(2mm)	538	<1(9mm)	241	2	190	<1(4mm)
19	330	<1(13mm)	560	10	234	<1(5mm)	190	<1(4mm)
20	346	2	540	<1(7mm)	238	1	188	<1(6mm)
21	348	2	541	<1(6mm)	238	1	190	<1(4mm)

NB. Percentiles from anthropometry survey of 2000 RAF male aircrew 1970/71 (Bolton et al, 1973[1]) except hand circumference which uses percentiles from anthropometry survey of USAF male flying personnel 1967-68 (Reference 2).

ADAPTATION MORPHOLOGIQUE ET FONCTIONNELLE DES EQUIPEMENTS DE VOL DESTINES AUX PERSONNELS FEMININS

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RESUME

Les équipements de vol sont destinés à protéger les personnels contre les effets défavorables du vol. Techniquement, ils fonctionnent soit en boucle fermée, soit en boucle ouverte. En boucle fermée, il existe un asservissement de la protection à la demande de l'utilisateur ; ces équipements ne posent généralement que peu de problèmes. Il n'en est pas de même des équipements en boucle ouverte, pour lesquels il n'existe qu'une relation statistique entre les caractéristiques de fonctionnement des équipements et les besoins de l'utilisateur. Ce sont ces équipements qui posent des problèmes d'adaptation à des équipages féminins. Concernant les équipements de protection respiratoire, de tels problèmes sont apparus pour les équipements à circuit ouvert de protection des personnels navigants techniques et pour les équipements de protection anti-fumée à circuit fermé destinés aux personnels navigants de cabine.

ABSTRACT

Personnal equipments are dedicated to protecting aircrews against adverse effects during flight. They operate either in close loop or in open loop. In close loop situations, there is a control of the protective device in relation to the user's demand so that such equipments create only a few problems. It is not so with open loop equipments in this case, there is only a statistical relationship between functionnal caracteristics of the equipemnts and the user's needs. It is especially difficult to adapt these equipments to female aircrews. As far as respiratory protection equipments are concerned, such problems have been noticed in open loop equipments for technical aircrews and in closed circuit smoke-hoods for cabin attendants.

INTRODUCTION

Les équipements personnels sont destinés à protéger les opérateurs humains contre certains des effets physiopathologiques spécifiques du vol, qu'il s'agisse de facteurs de l'environnement, tels que l'hypobarie, les facteurs thermiques ou toxicologiques, ou qu'il s'agisse d'effets biodynamiques tels que les accélérations. Du point de vue des principes physiologiques mis en application, la protection des personnels fait appel à des techniques que l'on peut classer en deux groupes. Le premier de ces groupes consiste à apporter la protection en fonction des besoins physiologiques du sujet : il s'agit alors d'un asservissement en boucle fermée du dispositif de protection en fonction des nécessités physiologiques du moment, ce qui ne pose a priori que des problèmes d'ordre technique. Le meilleur exemple en est donné par la fonction de demande des systèmes inhalateurs d'oxygène ; ce principe de fonctionnement des équipements de protection est malheureusement le plus rare. L'autre groupe de techniques est constitué d'équipements qui asservissent la protection en fonction des conditions de l'ambiance, en boucle ouverte par rapport à l'utilisateur, dont les besoins ne sont pris en compte qu'à travers une relation statistique, sans rapport autre que théorique avec les nécessités du moment. Un bon exemple en est donné avec le calcul des dimensions des équipements de secours, présentés en taille unique et adaptables, en théorie, à tous les utilisateurs. D'autres exemples seront donnés au cours de cet exposé, portant sur d'autres aspects physiologiques ; ce sont malheureusement les équipements les plus fréquemment employés. Nous traiterons dans cet exposé des équipements de protection respiratoire contre les facteurs d'ambiance.

Les équipements destinés à la protection respiratoire des personnels doivent pallier deux risques majeurs : le risque d'hypoxie d'altitude et le risque toxique en vol. Ces équipements font appel à deux types distincts de technologie : les équipements en circuit ouvert, traditionnels, dans lesquels les gaz expirés sont rejetés à l'extérieur, et les appareils à circuit fermé, dans lesquels les gaz expirés sont retraités et réinhalés. Jusqu'à un passé récent, ce dernier principe n'était pratiquement pas employé en aéronautique. Il vient de connaître un brutal regain d'intérêt dans le cadre de la protection des personnels navigants de cabine de l'aviation

de transport contre le risque toxique. De plus, il est souhaité que ces équipements de protection contre le risque toxique puissent également, dans toute la mesure du possible, être utilisés comme protection contre l'hypoxie accidentelle, ce qui complique encore leur mise au point.

En pratique, les principales difficultés rencontrées au cours des essais qui ont pu être réalisés au Laboratoire avec des personnels féminins concernent les fonctions suivantes : valeurs des débits et volumes gazeux ventilés, qui agissent sur certaines des conditions mécaniques de fonctionnement des systèmes, adaptation morphologique des équipements, conditions d'échanges gazeux à travers des espaces morts et des résistances ventilatoires additionnelles.

Systèmes respiratoires en circuit ouvert

Les systèmes respiratoires en circuit ouvert peuvent fonctionner selon deux principes distincts : systèmes dits à débit continu ou systèmes à la demande. Les systèmes à débit continu permettent l'arrivée d'un débit massique constant d'oxygène au masque respiratoire. Aucune observation expérimentale ne permet de mettre en évidence de différence de fonctionnement ou d'efficacité selon le sexe.

Il n'en est pas de même des systèmes respiratoires dits à la demande. Un système à la demande est en fait un dispositif complexe qui réalise entre autres trois fonctions : un asservissement en boucle fermée du débit gazeux délivré par le système en fonction de la demande inspiratoire du sujet (c'est cette fonction "de demande" qui sert à définir l'ensemble du dispositif), un asservissement en boucle ouverte de la fraction d'oxygène inhalée dans le mélange inspiré en fonction de l'altitude, enfin un ensemble de fonctions de surpression dont l'une est également un asservissement en boucle ouverte de la surpression respiratoire à l'altitude.

Les problèmes proviennent de la fonction de demande inspiratoire. Celle-ci est réalisée lorsque la demande inspiratoire, traduite en termes de variation de pression dans le masque, est mesurée par un capteur de pression qui, par un procédé quelconque, parfois purement mécanique, traduit cette information en ordre d'ouverture d'un clapet d'oxygène.

Nous avons été confrontés expérimentalement à un double problème : celui de la sensibilité des capteurs de pression, couplée au risque de mauvaise étanchéité du masque. Au Laboratoire, des incidents ont été observés avec des équipements de secours destinés à l'aviation de transport. Ces équipements sont présentés en taille unique. Leur dessin a été établi sur la base de données statistiques. Un joint souple permet, avec un serrage adéquat, d'assurer son étanchéité sur le visage. S'il est vrai que ce dessin est bien adapté à une population masculine, il n'en est pas nécessairement de même avec une population féminine et la perte d'étanchéité se traduit par une diminution voire par une absence d'efficacité du dispositif "de demande" inspiratoire. L'explication en est simple : une mauvaise étanchéité du masque est à l'origine d'une diminution de la dépression inspiratoire à l'intérieur du masque, minimisant ainsi la fourniture de gaz respirable par le régulateur d'oxygène. Dans certaines conditions, cette fourniture peut être annulée, à l'origine d'incidents hypoxiques en altitude.

Un autre type d'inconvénient a été observé au Laboratoire avec ce même équipement. Il est lié au fonctionnement du dispositif de dilution. Ce dispositif permet l'enrichissement des gaz inhalés en oxygène, automatiquement en fonction de l'altitude. Or sur tous les systèmes existant cette fonction est réalisée de la même manière, par appel d'air à la sortie du gicleur d'injection de l'oxygène. L'entrée d'air est freinée par une capsule anéroïde, qui règle ainsi le mélange air-oxygène. Le fonctionnement de ce dispositif est toujours dépendant du débit instantané, selon des lois qui sont variables selon le matériel considéré. Certains systèmes inhalateurs d'oxygène délivrent un mélange d'autant plus pauvre en oxygène que le débit inspiratoire est faible, d'autres systèmes présentent la caractéristique inverse. L'amplitude de ces variations peut d'autre part être fonction de la pression barométrique (altitude). Ce sont des problèmes de cet ordre qui ont été rencontrés pour la mise au point de masques-régulateurs à mise en place rapide, destinés au personnel navigant technique de l'aviation de transport lorsque, testant ces équipements sur des personnels féminins de petite taille, nous avons observé des valeurs de débit inspiratoire moyen de l'ordre de 5 $dm^3.min^1$ ou moins, avec des valeurs de fraction d'oxygène hors norme. Ce fait a nécessité un important travail d'adaptation des équipements.

Aucun équipage féminin n'étant jusqu'à présent prévu pour voler en France sur avions de combat à haute performance, nous n'avons pas recherché quelle pouvait être l'adaptation des équipements pressurisés de haute altitude. Deux aspects de cette adaptation seraient à évoquer. Ils tiennent au volume des poches de pressurisation et au rapport de leur volume avec les différents volumes et capacités pulmonaires. Les poches de pressurisation des équipements pressurisés sont en effet montées en parallèle sur le circuit respiratoire. Or les équipements développés en France permettent leur usage avec des mélanges air-oxygène, au lieu de l'oxygène pur utilisé jusqu'alors systématiquement. Montées en parallèle, les poches de pressurisation sont remplies de gaz identique aux gaz inhalés. L'expérience montre que, à chaque inspiration, le sujet inhale du gaz qui provient pour partie directement du régulateur d'oxygène et pour partie de la poche de pressurisation, dans un rapport qui varie en fonction du volume de la poche et du comportement ventilatoire du sujet, dans une

gamme de 40 à 70 p. cent de gaz provenant directement du régulateur d'oxygène. En cas de décompression rapide à haute altitude, il est nécessaire d'administrer de l'oxygène pur sans retard ; or la présence de gaz dans la poche de pressurisation ne permet pas d'obtenir cet objectif et des palliatifs doivent être trouvés, en optimisant les volumes et fractions gazeuses en fonction de la tolérance à l'hypoxie pendant une durée déterminée.

Le volume des poches de pressurisation et le rapport de ce volume par rapport au volume pulmonaire intervient également dans l'estimation de la protection contre la surpression alvéolaire au cours des décompressions explosives, pour que l'expansion volumétrique des gaz puisse assurer la contre-pression nécessaire.

Systèmes respiratoires en circuit fermé.

Les systèmes respiratoires en circuit fermé ont été récemment introduits de façon extensive en aéronautique. Il s'agit d'équipements prévus à l'origine comme dispositifs de protection contre les ambiances toxiques et dont il a été par ailleurs demandé qu'ils puissent assurer une protection convenable contre l'hypoxie d'altitude. Destinés aux personnels navigants de cabine de l'aviation de transport ils doivent permettre à l'utilisateur d'intervenir dans un foyer d'incendie en cabine ou en soute et doivent leur permettre un exercice physique intense, standardisé par la règlementation civile (Action Notice 8150-2). Dans les conditions décrites par l'A.N. 8150-2, il devient irréaliste de fournir le gaz respirable en circuit ouvert et le choix des différents constructeurs s'est porté sur des dispositifs en circuit fermé. Les équipements développés en France consistent en une cagoule divisée en deux compartiments dont l'un reçoit l'oxygène de réserve et l'autre est en communication avec les voies aériennes. Le transfert de gaz entre les deux compartiments s'effectue à travers des cartouches de chaux sodée chargées d'épurer le dioxyde de carbone.

Physiologiquement, l'inconvénient de ces systèmes repose sur la ventilation, qui s'effectue dans le compartiment de réserve à travers le compartiment antérieur. Celui-ci représente donc un volume mort additionnel non négligeable, malheureusement difficile à évaluer avec précision en raison de sa variabilité entre chaque sujet et de sa variabilité dans le temps : sa déformabilité n'est en effet pas négligeable au cours du cycle ventilatoire. Le volume de la tête est un facteur de variation important. L'autre facteur pris en compte est le volume courant ou, plus exactement, le rapport entre le volume mort additionnel et le volume courant.

Volume de la tête et volume courant plus faibles agissent simultanément pour augmenter le rapport du volume mort au volume courant et augmentent ainsi la réinhalation des gaz expirés. Les essais effectués chez le personnel féminin montrent une augmentation de la pression partielle inspiratoire en dioxyde de carbone, qui est en moyenne plus élevée de 0.5 à 1 kPa par rapport aux mêmes essais pratiqués sur une population masculine.

Fonction de protection contre les ambiances polluées

Les règlements applicables aux équipements de protection contre les ambiances polluées (par exemple le TSO C 99) prévoient explicitement que les tests soient effectués sur des sujets de chaque sexe. Deux fonctions doivent notamment être examinées au Laboratoire: l'étanchéité vis-à-vis du toxique et la préservation du champ visuel. Dans ce cadre nous avons à plusieurs reprises, effectuées des séries expérimentales distinctes selon le sexe. Elles permettent de décrire l'adaptation des équipements de vol selon le sexe conformément aux prescriptions réglementaires. Compte-tenu de ces exigences, il apparait que les constructeurs de matériel ont pris en compte ce fait, soit par adaptation morphologique (cas du champ visuel), soit par adaptation fonctionnelle des équipements (cas de la fonction anti-pollution), par exemple en adjoignant systématiquement une fonction de surpression aux équipements utilisés. Suite aux adaptations réalisées, il n'existe à l'heure actuelle plus de différence systématique d'efficacité ou de fonctionnement de ces équipements selon le sexe.

En conclusion, l'adaptation des équipements de vol aux personnels féminins a dû prendre en compte plusieurs considérations : morphologiquement, les différences de taille de certains segments corporels ont nécessité une adaptation parfois difficile en ce qui concerne les équipements de secours, présentés par principe en taille unique. Fonctionnellement, ce sont les variations des volumes et débits ventilatoires qui ont nécessité une extension du domaine de réglage de ces équipements.

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ACCOMMODATION OF FEMALE AIRCREW IN USN PROTECTIVE FLIGHT CLOTHING AND EQUIPMENT

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SUMMARY

The number of United States Navy aviation designated female personnel has increased substantially over the past two decades. Along with this increase has come the ever pressing requirement to provide these aircrewmembers with safe and effective protective clothing and life support equipment. This paper discusses a variety of problems which have arisen in attempting to accommodate these female aircrew in a clothing and equipment system which was designed for a male population. Although no overall integrated approach has been employed in this effort, a review of the various methods and solutions which have been successfully employed to address both the particular needs of individuals and the specific items of clothing and equipment are discussed. Based on a review of problem reports and personal contacts with currently designated female aircrew personnel, many problem areas remain. These areas are discussed as they will provide the basis for future work in this continuing effort.

INTRODUCTION

Although women have been active members of the United States Navy (USN) for many years, and served honorably during World War II as Women Airforce Service Pilots (WASPs), it was not until 1973 that the Navy allowed women to become Naval Aviators. This authorization was expanded in 1977 to include Naval Flight Officers (NFOs). The first eight female students started flight training in 1973 with the first woman Naval Aviator, then-Lieutenant Barbara Allen Rainey, receiving her wings in February 1974.[1] Along with that milestone, came the challenge to accommodate these women aviators and aircrew in USN aircraft cockpits, protective flight clothing, and life support equipment.

Initially, women were not allowed to fly jets, could not carrier qualify, and could not land aboard aviation capable ships. This policy was eventually changed, however, and women now do all of these things. Although still excluded from flying combat missions by United States statute, women aviators, from all of the U.S. military services, are currently flying most types of tactical jets, rotary wing, patrol, and cargo airframes. Along with their expanding realm of assignments and variety of aircraft flown, the number of female aircrew has steadily increased over the past 17 years as well. As of December 1989, 306 women have been, or are currently, designated as Naval Aviators and Naval Flight Officers (NFOs). In addition, over 500 enlisted women have been designated as aircrewmembers. Despite the continuing influx of females into military aviator and aircrew ranks, there has not, as yet, been an overall integrated approach to accommodating these women in Navy aircraft, or to establishing personal equipment oriented toward their peculiar needs. This is not due to a lack of interest in them, but rather, to the always-present limits on funding and manpower which are even more prevalent today. Unfortunately, the problems associated with minority segments often go untended in such an austere funding climate. As a result, only minor changes have been effected on personal equipment which was originally designed for a specific segment of an exclusively male population[2] (5th to 95th percentile). Based on responses from active duty female aviators, this approach has resulted in achieving only a minimally acceptable level of performance.

GENERAL FLIGHT CLOTHING

The first items of protective clothing which received attention were, understandably, those items which were utilized by all female aircrew from all military services, specifically, flight coveralls, flight gloves, and safety boots. Prior to the entry of female aircrew, the CWU-27/P summer flyer's coverall[3] had been available in twenty-four sizes to accommodate chest circumferences from 36 to 48 inches (91.5 to 122 cm) and leg inseams from 26.5 to 30.5 inches (67.3 to 77.5 cm). This range was grossly inadequate to accommodate all but the largest female aircrew. As a result, four additional sizes, accommodating chest circumferences as small as 32 inches (81.3 cm),

but still maintaining a minimum leg inseam accommodation of 30.5 inches (77.5 cm), were added to the sizing tariff in 1977. Unfortunately, a 5th percentile female will more likely have a crotch to ankle measurement of only 24.5 inches (62.3 cm) despite her 32 inch chest measurement,[2] making the smallest size flight coverall unacceptable. Even for those female aircrew who are taller, and fall within the current leg inseam range, the overall fit of the flight coverall is not always acceptable. Since no redesign or repatterning of the flight coverall has been accomplished to reflect anthropomorphic differences in the female physique, many females must select larger size coveralls o accommodate a proportionately larger hip circumference. This often results in excess torso length and/or chest girth. At the present time, her alternative is to order custom-made flight coveralls, a costly and often time-consuming approach from the user and squadron viewpoint.

Since there are no gross anthropomorphic differences between male and female hands, other than overall size, the accommodation requirements for flight gloves were much simpler and the solution has been likewise, more successful. In, 1973, the GS/FRP-2 fire resistant flyer's glove[4] was introduced in six sizes (6 through 11). In order to accommodate females, a size 5 was added to the tariff in 1979. To date, this 7-size tariff has accommodated all but the most extreme individuals. Again, custom-made flight gloves are available when necessary.

For flight boots, available sizes in 1973 included 5 through 14 in narrow, regular, wide, and extra-wide widths as well as 8 through 14 in extra-narrow width. To accommodate both the increasing female aircrew population, as well as the increasing numbers of smaller males, sizes 4 through 14-1/2 boots, in all widths were made available in 1980. Finding a need to further expand the tariff, size 3 in all widths and size 2 in narrow through extra-wide widths were recently added to the specification in 1987[5]. Like the flight gloves, current boot sizing tariffs adequately accommodate virtually all male and female aircrew. Again, custom made boots are available for individuals with extreme requirements.

There are several other multi-service items currently being supported as standard issue items. These include a variety of flight jackets, cold weather trousers, and cold weather coveralls. Of these, only the CWU-64/P Cold Weather Coverall[6], which was recently introduced by the US Air Force, has attempted to address the accommodation of female aircrew. Like the CWU-27/P summer flyer's coverall, the CWU-64/P sizing tariff accommodates chest girths between 32 and 48 inches (81.3 to 122 cm) and leg inseams of 26.5 to 30.5 inches (67.3 to 77.5 cm) but does not reflect body proportions typical of the female. Sizing tariffs for the CWU-36/P Summer Jacket[7] and the CWU-45/P Cold Weather Jacket[8] have gone unchanged. They currently accommodate chest circumferences from 34 to 48 inches (86.4 to 122 cm). Since the fit of these items is generally not critical to an aircrewmember's performance, the lack of a smaller size has been tolerated. Likewise, no new sizes of CWU-18/P Cold Weather Trousers[9] have been added to the inventory. Currently available in waist circumferences between 28 and 46 inches (71 and 117 cm), they too are being tolerated by smaller individuals, primarily because of their design, which includes suspenders offering some limited adjustability for the small individual. As with the other multi-service items, procurement of custom-sized versions of all of these items is possible.

OXYGEN MASKS

The dual service MBU-12/P oxygen mask[10], which is jointly used by the USAF and USN, has always offered a challenge to fitting which was markedly exacerbated with the entry of females. The proper fit of the mask to the face is crucial to prevent air leakage and/or slip under high-G forces. Variations in facial contours, even within the average male aircrew population, have often caused problems. At the current time, the mask is available in four sizes including short, regular, long, and extra long, but is mounted in a single size hard cup. Although there are no "official" variations in width or shape, products delivered from the two current manufacturers of the mask do, in fact, vary in shape, nose bridge width and depth of chin area for the same size. Experience of the Navy field personnel responsible for proper fitting of the mask has been traditionally relied upon to exploit these differences and turn them into a fitting advantage. However, inability to acquire a given size mask from a specific manufacturer has at times been difficult or impossible. An extra-short size of this mask has also been developed by the USAF and should be procured in the near future. Unfortunately, the extra-short mask is designed using the same single size hard cup, for mounting of the inhalation/exhalation valve and hose, as is used in the longer size masks. This may cause the soft silicone rubber outer area, which seals to the face, to be spread wider than desired for optimum fit on the smaller face. The mask is held in place by offset bayonet fittings which interface with helmet mounted receivers, the location and attitude of which may be adjusted somewhat to the individual wearer. The MBU-12/P design is currently not available in custom-made masks. However, to accommodate individuals outside the anthropometric design range, both standard size and custom made MBU-5/P masks[11], the predecessor of the MBU-12/P, are still available. Due to the softer silicone rubber used throughout the face piece of the MBU-5/P mask and the separate hard cup, a better fit is generally possible. However, this mask has a tendency to slide down when subjected to a high-g environment and custom-made masks have a much shorter service life.

HELMETS

Turning attention to the helmet itself, the Navy currently utilizes many variations of two basic helmet assemblies, one for rotary wing applications and one for fixed wing applications. The rotary wing assemblies (SPH-3C) include a basic shell which is available in two sizes, regular and extra-large whereas the fixed wing assemblies have three basic PRK-37/P shell sizes, medium, large and extra-large. In both helmet types, the basic shell is custom-fit to the individual by way of a foam-fitting liner which is fabricated to conform specifically to the individual's head contours and size. The rotary wing helmet series also incorporates a 1/2 inch (1.3 cm) thick polystyrene liner which is located between the shell and the foam-fitting portion. This provides an increased level of impact protection over the tactical helmet. In addition, fitting pads provide optimum location and tension of earcups for each individual aircrewmember. This system works very well for the majority of male aircrew. For individuals with smaller head size, many of whom are female, however, the size of the regular, or medium, helmet shell is somewhat limiting. Based on the fitting guidance provided for the PRK-37/P shell, the medium size shell is designed to accommodate head circumferences between 21 and 23 inches (53.3 to 58.4 cm). Since a 5th percentile female aircrew is likely to have a head circumference as small as 20.6 inches (52.3 cm)[2], it is not surprising that it is difficult, if not impossible, to get an acceptable fit with the medium shell. Although most of these people can be fit in the medium, the helmet sometimes sits somewhat higher on the head than desirable resulting in a decreased level of helmet retention during ejection or decreased helmet stability during high-g loading. As a side issue, a prime concern in the tactical community is helmet weight. This concern has led to limited authorization of the HGU-55/P USAF helmet[12] which features a lighter visor system and an increased field of view. This helmet is also available in the same three basic shell sizes as the PRK-37/P and is custom fit to the individual by way of either a thermoplastic or foam-fitted liner system. Accommodation of the small head is not expected to be any better with this assembly.

ANTI-G GARMENTS

There are two different anti-g garments currently in use by the US Navy, the USN CSU-15/P[13] and the USAF CSU-13B/P[14]. The two garments are very similar in design and offer equivalent levels of g protection. Both are cutaway designs which provide bladder coverage to the legs and abdomen and include adjustment lacing areas designed to provide a snug, comfortable, customized fit for each individual aviator. With regard to size, the CSU-15/P is available in six sizes including small, medium and large in both regular and long lengths. The regular length sizes are all designed with a finished overall leg length of approximately 24 inches (61 cm) and the long length sizes have an overall leg length of approximately 26 inches (66 cm). Since the leg portion of this garment is designed to fit several inches above the ankle, i.e. above the top of the flight boot, 24 inches (61 cm) is too long for the smallest female (5th to 25th percentile) with a crotch to ankle measurement of only 24.5 to 25.7 inches (62.3 to 65.3 cm)[2]. This is further confirmed by Table 1 which provides the height and

TABLE 1
"IGHT AND WEIGHT RANGES
.5U-15/P ANTI-G GARMENT

GARMENT SIZE	HEIGHT (IN)	WEIGHT (LB)
Small Regular	64.0 - 68.5	129 - 156
Small Long	68.5 - 73.1	129 - 156
Medium Regular	64.7 - 70.3	157 - 184
Medium Long	70.3 - 74.5	157 - 184
Large Regular	66.8 - 71.7	185 - 212
Large Long	71.7 - 76.6	185 - 212

weight range guidance currently provided for this garment. Obviously, the minimum height of 64 inches (162.6 cm) and minimum weight of 129 pounds (58.5 kg) which is accommodated by the current sizing tariff of this garment excludes most female aircrew who fall below the 50th percentile female measurements[2] for height and weight. Likewise, the circumferential adjustability ranges provided by the six sizes do not accommodate the smaller females (see Table 2). In order to provide some additional circumferential adjustment, fleet modification of the garments is currently authorized. The modification involves removal of excess fabric by stitching in pleats near the lacing adjustment panels thereby reducing the overall circumference in those areas of the garment where needed, i.e waist, thigh and/or calf. Another modification, which has been authorized on a very limited case-by-case basis, involves shortening of the short length garments at the waist and/or calf portions by folding up the bladder, reducing the length of the bladder casing, and then reconstructing the bound edges of the

garment. It is probable that many more individuals could benefit from this modification but it is not in widespread use due to the complicated nature of the change. As of 1989, the CSU-15/P is no longer being procured and the US Navy is transitioning over to the USAF CSU-13B/P Anti-G Garment on an attrition basis.

TABLE 2
CIRCUMFERENTIAL ADJUSTABILITY RANGES (IN INCHES)
CSU-15/P ANTI-G GARMENT

Size	Small		Medium		Large	
	min	max	min	max	min	max
Ankle	8.75	12.00	9.88	13.25	11.88	15.25
Calf	13.00	16.88	14.38	18.50	15.13	19.00
Lower Thigh	14.13	18.38	11.13	15.63	17.00	21.75
Upper Thigh	19.00	24.00	20.75	25.75	22.50	27.75
Waist	29.75	35.75	33.00	39.50	35.75	42.75

The CSU-13B/P sizing tariff includes an additional size Large X-Long to accommodate the extremely tall individual but still offers no size appropriate for the smallest female aviator. Although the stature and weight ranges provided as guidance for this garment (See Table 3) indicate accommodation of personnel down to a height of 63

TABLE 3
HEIGHT AND WEIGHT RANGES
CSU-13B/P ANTI-G GARMENT

GARMENT SIZE	HEIGHT (IN)	WEIGHT (LB)
Small Regular	63.0 - 67.9	131 - 160
Small Long	68.0 - 72.9	131 - 160
Medium Regular	64.5 - 69.4	161 - 190
Medium Long	69.5 - 74.4	161 - 190
Large Regular	67.0 - 71.24	191 - 220
Large Long	71.25 - 75.4	191 - 220
Large X-Long	75.5 - 79.0	191 - 230

inches (160 cm), the shortest leg length, which is provided by the small regular size, is in fact 26 inches (66 cm) the same as the long length USN CSU-15/P and 2 inches (5.1 cm) longer than the shortest CSU-15/P. Likewise, the circumferential adjustability ranges of this garment (See Table 4)[14] offer no advantage to the small female. While modifications similar to those described for the CSU-15/P are possible with this garment, it is clear that the addition of a small short, and possibly even a medium short, size to the tariff for this garment would greatly enhance accommodation of the female aviator population.

ANTI-EXPOSURE ASSEMBLIES

Another group of protective clothing items which are of particular concern to the US Navy are the assemblies worn to provide immersion hypothermia protection in a survival situation. At the time females entered the USN aviator ranks, the CWU-33/P Anti-Exposure Coverall[15] was in use. This garment consisted of a polychloroprene foam wet suit innershell covered by a separate high temperature resistant aramid outershell. The garment was available in twenty sizes accommodating a height range of 64 to 77 inches (162.6 to 195.6 cm) and a weight range of 138 to 206 pounds (62.6 to 93.4 kg). Some customization of size was possible, but again smaller females were generally far outside the normal tariff.

In the late 70's, the Navy abandoned this assembly and adopted the USAF CWU-21/P Assembly[16], primarily as a result of strong encouragement from the Fleet. The CWU-21/P assembly was based on a single layer ventile cotton "dry" suit concept which also included a CWU-23/P mesh liner[17], SRU-25/P cotton flocked rubber socks[18] and polychloroprene coated nylon neck and wrist seals. The sizing tariff for both the CWU-21/P outer coverall and the CWU-23/P liner included twelve sizes accommodating a height range of 63 to 76 inches (160 to 193 cm) and a weight range of 125 to 224 pounds (56.7

TABLE 4
CIRCUMFERENTIAL ADJUSTABILITY RANGES (IN INCHES)
CSU-13B/P ANTI-G GARMENT

Size of Anti-g Garment	Waist Circ min	Waist Circ max	Thigh Circ min	Thigh Circ max	Ankle Circ min	Ankle Circ max	Leg Length
Small Regular	29.50	34.50	21.00	26.00	12.00	15.00	26.00
Small Long	29.00	34.25	20.75	25.50	12.00	15.00	28.00
Medium Regular	32.25	38.25	22.25	27.25	12.00	15.00	26.50
Medium Long	32.00	38.00	22.50	27.50	12.00	15.00	28.50
Large Regular	35.25	41.00	23.50	28.75	12.00	15.00	27.00
Large Long	35.50	41.25	24.00	29.00	12.00	15.00	29.00
Large X-Long	35.50	41.25	24.00	29.00	13.75	16.75	33.00

to 101.6 kg). Due to the extremely limited availability of ventile cotton cloth to produce these coveralls, the Navy immediately had difficulty obtaining sufficient quantities of garments to meet their needs. An almost immediate search for a replacement fabric led to the development of the CWU-62/P Anti-Exposure Coverall[19] which is in use today.

The CWU-62/P Coverall is fabricated of a waterproof breathable laminate material, and as originally introduced, included cotton flocked rubber neck and wrist seals. Otherwise, the design and sizing tariff of the CWU-62/P is identical to the USAF CWU-21/P. With regard to accommodation of the female aircrew population, this coverall has not been without its problems. Once again, the smallest (5th to 25th percentile) females[2] are outside the design range of the garment. Even among those females who do fall within the basic sizing range, some have had difficulties due to the fact that the coverall is proportioned for the male anthropomorphic body type. Very often, the appropriate size suit for their height is too narrow in the hips requiring them to wear a larger size suit. This results in too much material in the shoulders and waist, creating bulk under other flight garments and ultimately pressure points. This garment is not currently available for custom-size procurements. As a result, some modifications to add gussets of material in the hip area or to shorten the coverall in the waist area have been made by Fleet maintenance activities, on an as needed basis. The coverall is also customized for all users with regard to sizing of the neck and wrist seals and requires the addition of appropriately sized rubber socks.

As part of a product improvement effort to improve both comfort and fit, natural polyisoprene rubber neck and wrist seals were developed for the CWU-62/P in 1988. These seals are currently undergoing procurement action but have already been procured using open purchase methods since December 1989. The neck seals come with molded-in trim lines and are trimmed to fit each individual's neck circumference. The wrist seals are cylindrical in shape to distribute the tightness and provide a better seal. They currently come in four sizes which will accommodate down to a wrist circumference of approximately 5.75 inches (14.6 cm). Unfortunately, this lower limit does not include females below the 50th percentile for wrist circumference[2]. However, custom made seals are available and a fifth size will be added in the near future to accommodate these individuals.

The SRU-25/P cotton flocked molded rubber socks[18], which are currently attached to the CWU-62/P coverall assembly, are available in eight sizes ranging from 5-1/2 to 12. They have presented numerous fitting problems both because of their size range limitations and due to their design which is very tight across the top of the foot. These socks have also had a poor durability record requiring frequent replacement. In order to overcome these deficiencies, new socks, fabricated of a waterproof breathable stretch laminate material, have been designed and are currently undergoing procurement action. These socks, designated CWU-75/P, will be available in sizes 4 through 13 corresponding to normal boot size. Due to their sewn and taped seam construction, custom-made socks for individuals outside this sizing tariff can be more easily manufactured than with a one-piece molded construction such as was used for the SRU-25/P socks.

The CWU-62/P coverall is part of the A/P22P-6A(V)2 Anti-Exposure Assembly which also includes thermal underwear and an anti-exposure liner. The thermal underwear, CWU-

43/P drawers and CWU-44/P undershirt[20], are fabricated of high temperature resistant, waffle knit, aramid cloth and were originally introduced in 1976 in four sizes, small through extra-large. In 1979, a fifth size, extra-small, was added primarily to accommodate female aircrew. The current sizing tariff accommodates chest sizes from 30 to 49 inches (76.2 to 124.5 cm) and waist circumferences from 22 to 41 inches (55.9 to 104.1 cm). This tariff now includes all aircrew, male and female. However, personal contacts with female aircrew indicate that the fit of the drawers is still less than optimum due to the presence of the fly and the male proportional fit.

The original CWU-23/P mesh liner[17], was introduced along with the CWU-21/P coverall but remained a part of the anti-exposure assembly with the introduction of the CWU-62/P. It is available in the same twelve sizes and size range as the CWU-62/P. It is still used by the majority of USN and USAF aircrew, even though a new CWU-72/P liner[21], was introduced in 1987. The CWU-72/P is fabricated of olefin microfiber insulation sandwiched between two layers of high temperature resistant aramid woven fabric. It features short sleeves and legs which end mid-thigh and is available in nine sizes accommodating a height range of 63 to 77 inches (160 to 195.6 cm), a weight range of 120 to 200 pounds (54.4 to 90.7 kg), and a chest size of 32 to 45.5 inches (81.3 to 115.6 cm). When it was patterned, an attempt was made to proportion the smaller sizes of this liner to accommodate the female anthropormorphic shape. Since this liner is being introduced into service only as CWU-23/P liners become unserviceable, it is as yet unknown how well the female aircrew have been accommodated.

INTEGRATED TORSO HARNESS

The MA-2 integrated torso harness[22] serves as both a parachute harness and an aircraft restraint garment. This garment was introduced in the late 1950s as a personally issued harness worn by all Naval aircrewmembers who fly ejection seat equipped aircraft, such as the F/A-18 Hornet and the AV-8 Harrier. When women were first allowed to fly as crewmembers in ejection seat equipped aircraft, they had to wear one of the twelve sizes then available. For almost all of the women, the smallest MA-2, which was sized for the 5th percentile male, did not provide sufficient restraint for even low-g aircraft maneuvers or for acceleration loads incurred during ejection and parachute opening distribution.

In preparation for the first female midshipmen who were to be provided Navy jet familiarization flights in the summer of 1977, a number of the smallest MA-2 harnesses were dimensionally downsized one size and made available to fit the small statured midshipmen. This harness was used in an attempt to fit over fifty female midshipmen. This evaluation revealed that while some women were accommodated by the smaller size, others were still inadequately fitted. Further work with female aviators led to the conclusion that for some small statured personnel, interactions among harness hardware, restraint webbing, parachute risers, and other personal equipment, especially helmets, were potential sources of severe injury.

From an intensive program assigned to the Naval Weapons Center by the Naval Air Systems Command, came the following solutions which have improved the fit and use of the MA-2 for all flight personnel:

- custom fit for selected personnel
- addition of three small and three large sizes to better accommodate the normal range of aircrew personnel
- establishment of firm fit criteria which identified the spatial relationships of critical pieces of aircrew life support system (ALSS) hardware for each person
- modification of the harness with two straps on the lower torso which were individually fitted and adjusted to maintain the proper positioning of the harness sling under the hips, ensuring proper distribution of parachute opening forces.

Even with the down sizing of the harness, fitting female aircrewmembers is still a problem. Difficulties center around the amount of rise in the harness when the candidate is suspended in the harness. The rise is caused by the harness displacing the fleshy tissues (fat) in the gluteal fold area of the buttocks. The Naval Weapons Center is observing approximately 4 to 8 inches (10.2 to 20.3 cm) of rise in the harness because of this tissue displacement. Reduction of the harness displacement is accomplished by shortening the harness saddle, creating a tighter fit around the legs and buttocks. A total elimination of harness rise has only been possible on female aircrew who have minimal fat around the gluteal folds. Because the harness will still rise on the torso of the female aircrewmember, it is necessary to ensure that the harness chest strap is even with or above the center of the breast mass. Failure to have the chest strap at or above the center of mass will subject the breasts to possible major injury during parachute line stretch (opening shock). Once the harnesses have the saddle shortened and the chest strap raised, the female aircrew are briefed on special donning procedures for females. Specifically, they are instructed to tighten the harness as tight as they can bear, sit in the ejection seat, loosen the chest strap, tuck or press the breast below the chest strap, and then retighten the chest strap to a tight but comfortable position. Most of the problems with fitting female aviators are expected to be solved with the introduction of a new adjustable MA-2 style harness with two channels for chest strap routing. Sizing with the new harness will effectively add two smaller sizes than the current MA-2 extra-small short harness.

CONCLUSIONS

In assessing how well female aircrew have been accommodated by the US Navy up to this point in time, it becomes obvious that the lack of a coordinated approach to the effort has resulted in only moderate success in meeting the needs of this vital component of the flying population. Although minimal efforts have been undertaken to add smaller sizes of some items, numerous problems remain with the fit, sizing, and functionality of the female aircrewmember's flight clothing and life support equipment. Immediate attention should be given to those items which are currently unavailable for custom-sized procurement and which directly affect the aircrewmember's ability to safely perform her mission or which threaten her survivability in an emergency. Included in this category are the anti-g garment, the helmet, and the anti-exposure coverall and its components. At the present time, it is virtually impossible to provide many of our female aircrew with an acceptable fit in these items. For the anti-g garment and helmet, addition of smaller sizes will most likely solve the problem. For the anti-exposure garment, several new sizes, proportioned to accommodate female anthropometry will most likely be required.

A complete effort should then be undertaken to redesign, not just resize, all items of general flight clothing including coveralls, underwear, jackets, and trousers which require a different proportional distribution for female accommodation. This effort should include incorporation of design features, such as drop seats, which address the female requirement for body waste elimination, a critical need especially during long duration flights. This capability is also needed in the anti-exposure coverall design. Once sizes are established, adequate supplies should be procured and stocked to assure availability and eliminate the long lead times and excessive costs associated with procurement of custom-size items. Completion of this effort would greatly benefit the over-1800 US female aircrew who are distributed among the military services, since most of the general flight clothing items have multi-service application.

Finally, an accurate anthropometric data base for female aircrew should be established and included in all military specifications and operational requirements documents for aircraft and flight equipment. This will assure that the female aircrewmember will be addressed during the development of any new or improved airframes, flight clothing, and life support equipment in the future.

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12. Military Specification MIL-H-87174 Helmet, Flyer's, HGU-55/P
13. Military Specification MIL-A-81905 Anti-G Garment, Cutaway, Aramid, CSU-15/P
14. Military Specification MIL-A-83406 Anti-G Garment, Cutaway, CSU-13B/P
15. Military Specification MIL-I-81902 Innershell, Coverall Assembly, Flyer's, Anti-Exposure, CWU-33/P, Insulating and Ventilating, Cellular Rubber
16. Military Specification MIL-C-83195 Coveralls, Flyer's Anti-Exposure, CWU-21/P
17. Military Specification MIL-L-83197 Liner, Anti-Exposure, Flying Coveralls, CWU-23/P
18. Military Specification MIL-S-83194 Socks, Men's, Anti-Exposure, Rubber, SRU-25/P
19. Military Specification MIL-C-85633 Coveralls, Flyer's Anti-Exposure, CWU-62/P and CWU-74/P
20. Military Specification MIL-D-85040 Drawers and Undershirts, Flyer's, Anti-Exposure, Aramid, High Temperature Resistant, CWU-43/P and CWU-44/P
21. Military Specification MIL-L-85701 Liners, Flyer's, Anti-Exposure Coverall, CWU-72/P
22. Military Specification MIL-H-19089 Harness, Integrated Parachute

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VARIABILITE DE LA FORCE MUSCULAIRE ENTRE LES HOMMES ET LES FEMMES

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RESUME -

La nécessité de mettre à jour et de compléter les recommandations sur les efforts admissibles dans la manipulation de commandes s'impose car les données récentes demeurent parcellaires pour les hommes, et elles sont pratiquement inexistantes pour les femmes.
Par ailleurs, il existe des différences très importantes en termes de niveau moyen et de variations interindividuelles entre les hommes et les femmes. Ceci a été montré par maints travaux aux Etats-Unis. Toutefois la comparaison des résultats des différentes enquêtes fait apparaître un certain nombre de discordances qui doivent, pour une large part être imputables à l'utilisation de procédures de tests différentes.
A partir de ces travaux on peut cependant noter que les recommandations retenues pour le 5ème percentile homme excèdent très fréquemment le niveau admissible pour le 95ème percentile femme.
Afin d'actualiser ces données pour la population française, une expérimentation est en cours, en incluant des évaluations sur des femmes. Un protocole standardisé a été mis en place avec la mesure, pour le membre supérieur sur des sujets assis et sanglés, d'efforts isométriques de traction-compression et de torsion. Les résultats sont présentés en fonction de l'orientation de l'atteinte ainsi que de la direction préférentielle ou imposée de l'effort.

1 - INTRODUCTION -

Avant de songer à répondre aux besoins en données sur la force humaine musculaire, manifestés en permanence par les ingénieurs de conception, il n'est pas inutile de rappeler les difficultés intrinsèquement liées à cette recherche. Si la notion de force est intuitive, sa représentation objective par une mesure soulève bien des questions et ouvre un grand nombre de possibilités de choix. Faut-il mesurer un effort statique (isométrique) ou dynamique, et dans ce cas avec quel programme de vitesse d'exécution ; quel est, s'il existe, le lien entre les deux ? Peut-on considérer que l'effort exercé dans telles ou telles conditions concerne un ensemble musculaire limité, ou met invariablement en jeu la totalité du système musculaire ? Après toutes ces questions il convient encore de mentionner les différents facteurs de motivation associés à l'exigence de l'accomplissement d'un effort maximal. L'ensemble de ces problèmes qui ont été discutés dans une publication récente [1], conduit à énoncer que tout résultat expérimental fourni en la matière doit être indissolublement lié à un protocole expérimental précis et garde peu de valeur dès qu'on s'écarte un tant soit peu des conditions d'exécution correspondantes.

Cet état de fait impose une utilisation circonspecte des données souvent incomplètes existant dans la littérature [2] et rend souhaitable leur actualisation dans un cadre bien contrôlé. C'est dans ce but qu'a été entrepris la constitution d'un atlas de la force musculaire humaine incluant hommes et femmes. Ceci est un point important car les données concernant la population militaire féminine de France sont pratiquement inexistantes, au moment où la participation de cette population à un nombre croissant de missions doit être envisagée.

Fréquemment les concepteurs semblent s'appuyer sur une règle globale selon laquelle la force musculaire globale des femmes est aux deux tiers de celle des hommes [3]. Divers

travaux tendent à établir le caractère fallacieux de cette loi des deux tiers [4], [5], les différences constatées en pourcentage entre les hommes et les femmes s'étalant largement de part et d'autre de ces valeurs des deux tiers. Il est donc préférable d'un point de vue pratique d'expérimenter de façon systématique sur les deux classes de sujets qui pourront être comparées a posteriori. On examine ici les premiers résultats obtenus concernant les efforts isométriques de traction et de torsion sur une poignée, prise dans la main droite.

2 - PROTOCOLE EXPERIMENTAL -

La position du sujet est celle d'un opérateur assis à un poste de travail. Pour réaliser les différentes implantations du point d'exercice de l'effort par rapport au siège, c'est ce dernier qui se déplace, l'organe de mesure étant fixe.

Le sujet est sanglé au dossier de son siège avec les pieds simplement appuyés de façon à prévenir tout arc-boutement, l'usage du membre supérieur gauche étant interdit. Ces dispositions visent à limiter les groupes musculaires mis en jeu à ceux du membre supérieur droit, l'effort de réaction étant encaissé par l'interface tronc-sangles.

L'appareil de mesure est une poignée, constituée par un cylindre métallique vertical de hauteur 150 mm. et de diamètre 25 mm., garni d'un revêtement de tissu pour améliorer le confort de la saisie et éviter le glissement, cette forme permettant l'effort de traction optimal [6]. La poignée comprend un double capteur (quartz piézo-électrique) permettant la mesure simultanée d'un effort de traction-compression suivant la direction sensible, ainsi qu'un couple autour de cette direction. Il est ici utilisé pour mesurer la traction exercée sur la poignée, aussi bien que le couple résultant d'un effort de torsion à gauche tendant à un dévissage.

Dans les deux cas il s'agit donc d'une mesure sans déplacement, compte tenu de la déformabilité quasi nulle de ce type de capteur. Ceci peut présenter un inconvénient puisque l'effort s'exerce sans résultat mécanique perceptible. Compte tenu de l'expérience antérieure on pallie ce défaut en offrant au regard du sujet la visualisation sur un diagramme force-temps (oscilloscope) de l'enregistrement en temps réel de son action ; cette disposition améliore la reproductibilité des mesures, et conduit en général à une meilleure efficacité dans l'obtention de l'effort maximal.

L'expérimentation proprement dite se déroule sous la conduite d'un moniteur. En condition initiale l'opérateur est au repos la main sur la poignée, positionnée à sa distance d'atteinte fonctionnelle. L'effort débute sur l'ordre du moniteur avec mission d'atteindre et de maintenir le maximum possible jusqu'à l'ordre d'arrêt. Les durées demandées sont de l'ordre de 5 s. pour la traction et de 2 s. pour la torsion. Ces durées sont fixées relativement à la pénibilité du maintien de l'effort maximal.

La position de la poignée relativement au sujet est fixée par un système de coordonnées sphériques dont le centre est un point de référence pris à l'épaule (acromion), et les angles sont un azimuth (θ) dans le plan horizontal de ce point et une hauteur (z) relative à ce plan horizontal, la distance radiale correspondant à la distance d'atteinte fonctionnelle (figure n°1).

Dans les expérimentations présentées ici la hauteur reste nulle, toutes les implantations étant donc à l'horizontale de l'épaule. Les positions relatives de l'épaule et de la poignée ayant été fixées, il est alors nécessaire de préciser la direction de l'axe de mesure des tractions-torsions qui peut théoriquement être quelconque dans l'espace. Ici ont été retenues deux directions correspondant à deux situations extrêmes.

La première est dite préférentielle et consiste à aligner l'axe sensible du capteur avec la direction du bras étendu à la distance d'atteinte fonctionnelle.

La seconde est dite imposée : c'est la direction sagittale pour le sujet assis au repos. Cette situation correspond à un ensemble de manoeuvres en permanence perpendiculaire à un panneau frontal (figure n° 2).

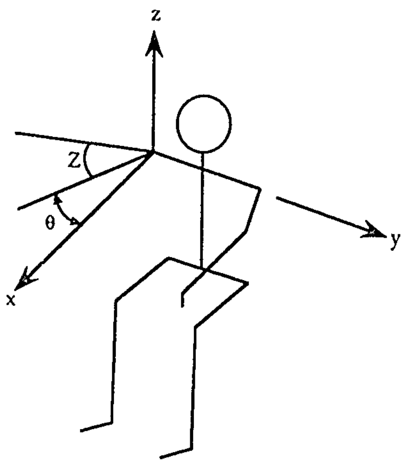


Figure n° 1
Le système de coordonnées.

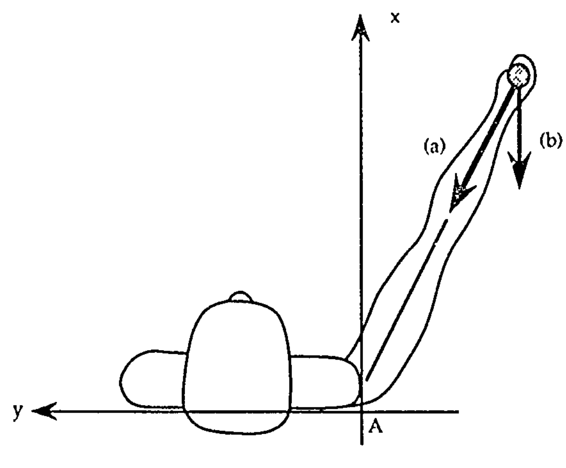
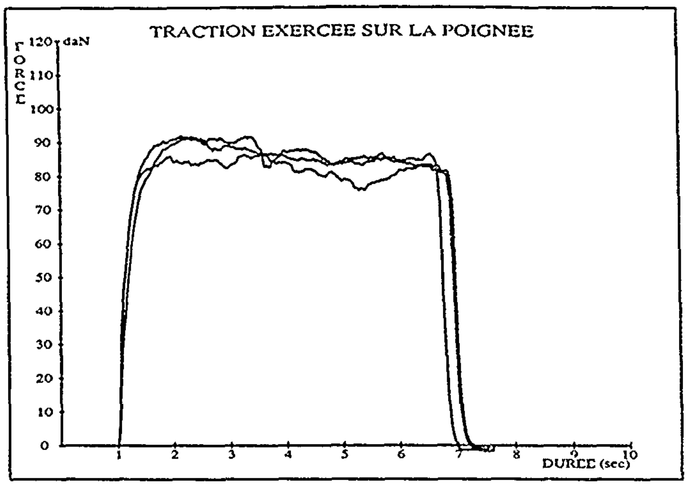


Figure n° 2
(a) - Axe de la traction-torsion préférentielle.
(b) - Axe de la traction-torsion imposée.

3 - LES RESULTATS -

Les expériences dont il est question ici ont concerné 16 sujets masculins et 6 sujets féminins : les implantations, toutes à hauteur nulle, ont été variées en azimuth au pas de 30°, de + 30° (à gauche) à - 90° (à droite) et chaque essai de traction et de torsion a été répété 3 fois, ce qui consitue un ensemble de 660 mesures.

Les enregistrements réalisés ont l'allure typique représentée sur les figures n° 3a et 3b. La superposition de trois essais successifs réalisés par un même sujet permet d'apprécier la reproductibilité de ces essais. On observera également qu'un effort de traction ou de torsion n'est jamais pur et qu'il s'accompagne inéluctablement d'une composante de torsion ou de traction résiduelle.



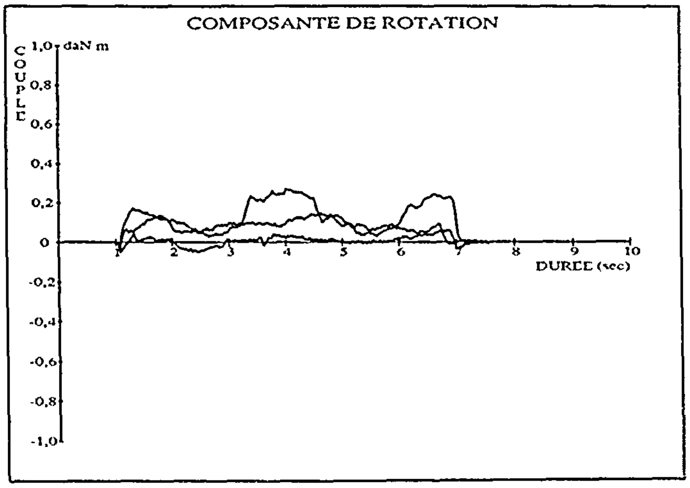
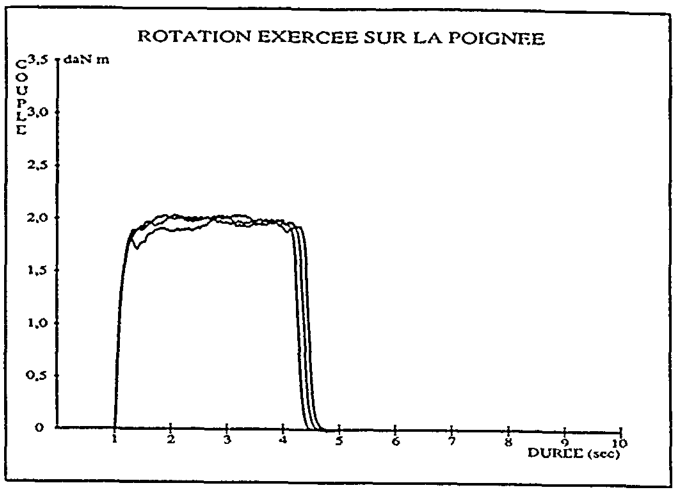


Figure n° 3a
Trois essais de traction et la composante de torsion associée.

De chacune de ces courbes, on extrait deux valeurs numériques caractéristiques : la valeur maximale de l'effort instantané et la valeur moyenne calculée sur une période dite de plateau excluant les temps de montée et de descente. Pour cela on détermine les instants de début et de fin de l'effort, comme ceux où le niveau de montée ou de descente franchit un seuil égal à 5% du niveau maximal ; la valeur moyenne est alors calculée dans une période centrée au milieu de l'intervalle de temps ainsi défini et d'une durée de 3 secondes pour la traction et 1 seconde pour la torsion.



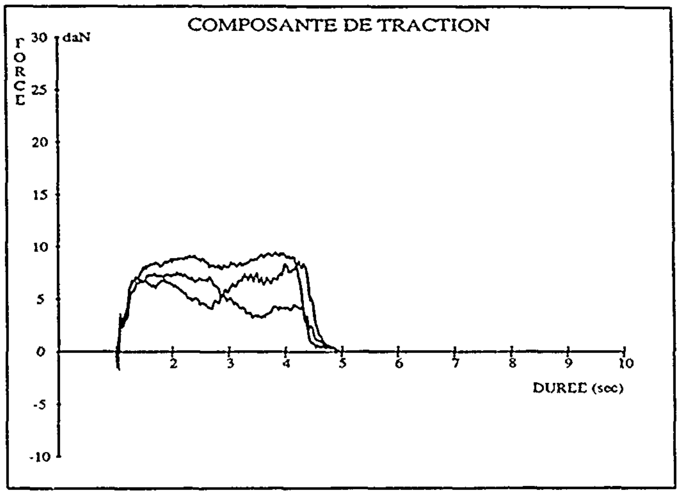


Figure n° 3b
Trois essais de torsion et la composante de traction associée.

Il existe des différences importantes entre les valeurs maximales et moyennes : les écarts varient entre 0 et 50% pour l'ensemble des six sujets féminins étudiés, sauf dans le cas de la torsion imposée où ils atteignent 100% (c'est évidemment la configuration où il est le plus difficile de maintenir durablement l'effort maximal).

On s'attache ici à la présentation des efforts maximaux exclusivement. Les courbes de la figure n° 4 permettent de comparer leur valeur moyenne pour les échantillons de femmes et d'hommes, tant pour les efforts de traction que de torsion, l'orientation de la poignée variant de + 30° (à gauche) jusqu'à - 90° (à droite). L'évolution de ces courbes est sensiblement identique pour chaque classe de sujets, mais avec des niveaux très différents et qui s'écartent notablement de la "Règle des deux tiers".

Pour les efforts de traction, on note une forte dégradation de la performance lorsqu'on s'éloigne du plan sagittal, effet qui s'accentue dans le mode imposé. Cette évolution ne se retrouve pas pour la torsion tout simplement parce que le mode d'exercice de l'effort devient très différent au niveau du poignet, passage progressif de la prono-supination (articulation du

poignet bloquée) à un mouvement d'inclinaison radiale et inclinaison cubitale du poignet (coude bloqué) Le tableau 1 donne les pourcentages d'écarts entre les hommes et les femmes dans les différentes situations étudiées.

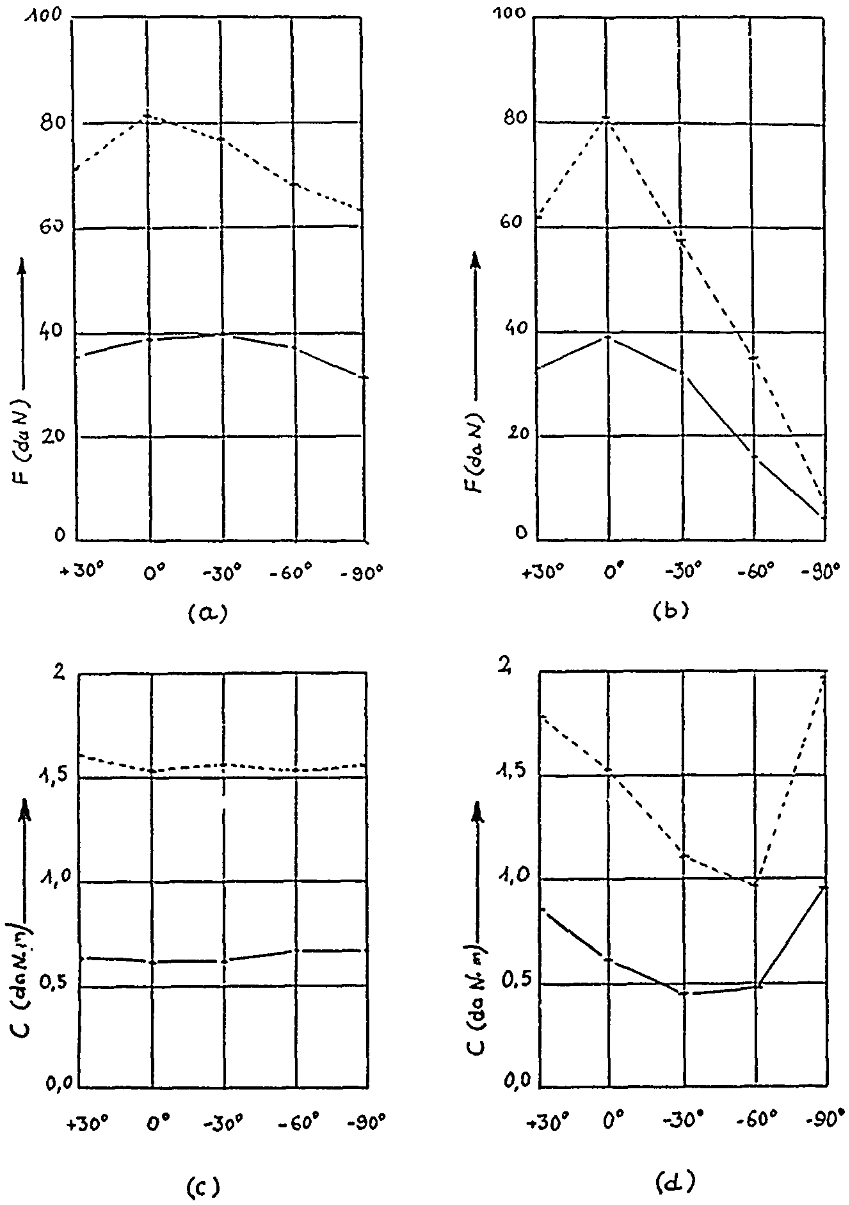


Figure n° 4
Comparaison des efforts : Femmes (—) et Hommes (....)
pour différentes implantations de la poignée :
Traction : (a) préférentielle, (b) imposée.
Torsion : (c) préférentielle, (d) imposée.

Position	Traction		Torsion	
	Préférentielle	Imposée	Préférentielle	Imposée
+ 30°	49	46	61	52
0°	51	51	60	60
- 30°	48	44	60	58
- 60°	45	53	57	49
- 90°	50	39	57	52

Tableau n° 1
Ecarts en pourcentage des valeurs moyennes des efforts maximaux des femmes par rapport aux hommes.

CONCLUSION -

L'ensemble des essais montre un écart important entre la performance des hommes et des femmes. Pour les actions considérées la performance féminine s'échelonne entre la moitié et les deux tiers de celle des hommes. Ce résultat ne peut cependant pas être généralisé, ni comparé aux données qui intègrent dans l'évaluation de la force, l'ensemble des groupes musculaires. Néanmoins les écarts mis en évidence ici sont largement suffisants pour motiver une étude spécifique systématique des populations féminines.

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PREGNANCY - A CAUSE FOR GROUNDING OF FEMALE AIR CREW

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Although female aviators, pregnant air crew in particular, is a novelty to most practitioners of military aviation medicine, gestation is not in itself an unusual condition, rather a natural process in the reproduction of the species - the biological destiny of female life so to speak. But, whereas the common complications of pregnancy are well known and the recommended means of treatment largely agreed upon, aeromedical specialists nevertheless appear to entertain differences of opinion with respect to precautions to be taken and restrictions to be imposed on the flying status of pregnant fliers.
One major difficulty of the problem to be addressed is, no doubt, that conception and gestation are perfectly normal conditions. Therefore, many women - aviators not excluded - feel justified in arguing that pregnancies ought not interfere with their professional life. The fallacy of this line of reasoning is, evidently, that gestation is not an uneventful state, albeit natural. Thus, the pathological events to be encountered during the period of gestation have to be assessed for incidence and severity relative to the requirements of operational military aviation, i.e. to what extent pregnancy might be expected to interfere not only with flying safety, but equally with combat readiness and mission completion.

On embarking on such a fact-searching endeavour, it seems appropriate to remind everyone concerned of the purpose of aviation medicine as a specialty within the general field of occupational health service with special emphasis on its preventive aspects.
Society, obviously, regard military aviation as rather a demanding profession. Moreover, public expenditures in air defence systems are considerable. Consequently, certain steps have been recommended in order to protect national investments and interests and third part liabilities. One special measure called for is to provide support for those engaged in military flying. Experiences of the past have shown that man is regularly taken to his limits of physical and psychological normal function during flight, thus, the human factor constitute a very vulnerable link in the organization of man and machine. For this reason aviation medicine is aimed at ensuring safe operations by generally to promote aviator health, and, specifically, to minimize occupational hazards to vital functions, the two factors to which the specialty owes its very existence.
On the assumption that this line of argument is largely acceptable to the comunity of aeromedical specialists, the medical prioritiespertinent to pregnant aviators appear not to differ from those which are applicable to air crew in general.
Firstly, every effort has to be made to identify and to avoid medical conditions which might possibly cause sudden incapacitation, especially those which may be due to collapse of vital organ systems or excruciating pain, since such events constitute direct threats to flying safety, thus, being capable of causing disasters.
Secondly, it is appropriate to exclude from flying duties - at least temporarily - those suffering from medical nuisances which are likely to annoy, disturb or to cause mental distraction which might interfere the successful completion of any given mission.
Thirdly, conditions which restrict free movements or cause obstructions to the extent of limiting the usefulness of equipment based on normal ergonometry are not acceptable, partly because operative requirements are interfered with, partly due to increased risks during execution of emergency procedures.
Finally, inconveniences which reduce effectiveness in flight are discouraged.

Now, the logical question to be asked is: are there any complications to pregnancy capable of causing events which interfere with flying duties as outlined above?
If the answer is affirmative, how severe is pathology involved, and, what is the rate of incidence of events?
In order to make the inquiry simple, the period of gestation might be divided into three trimesters with the typical complications of each trimester listed for a discussion.
Starting with the third trimester, the events to be expected during this last period of gestation and their consequences for female air crew seems to be largely agreed upon. Most of those concerned, physicians, female aviators and operative leaders alike, seem to appreciate the fact that the bodily changes, abdominal enlargement in particular which normally takes place, interfere with fitness for flight. Moreover, a premature delivery is always a possibility to be taken into account. Furthermore, the pregnant female should be regularly controlled and closely supervised during this last third of the period of gestation since toxaemia of pregnancy might develop. An overall figure for Norway indicate that approximately 5 per cent of all pregnant females will exhibit symptoms or signs suggesting preeclampsia (Bjøro & Molne 1972). Thus, the complications which may take place during the third trimester fit all of the categories of undesirable events discussed above. Consensus seems to exist with respect to a decision of temporary grounding of pregnant aviators during the last trimester. Accordingly, the flying career of a pregnant female would not be extended beyond approximately 28 weeks in any event.
The second trimester may be considered a relatively safe period of gestation for the pregnant aviator as well as for her foetus. The organ systems of the foetus have been differentiated and developed and the pregnancy is stable, although late spontaneous

abortions occasionally do take place. Abdominal enlargement is not yet likely to interfere with the flying task. Pregnancy is hardly an absolute counterindication to flight during the second trimester.
The first trimester appears to be thought of as quite an uncomplicated period of gestation by professional females. In our opinion such a position is highly debatable, especially if the professional duty is a demanding task like military flying with the additional possibility of being hours away from facilities with trained personell and equipment suitable for immediate intervention in the case of a medical emergency. Obviously, medical emergencies may affect any crew member male or female, however, the essential question remains, as already pointed out, whether or not pregnant air crew is more at risk than other aviators. We would like to submit that they are, indeed.

Pathological manifestation of pregnancy which might interfere with flying safety and accomplishment of missions are likely to take place with such a high incidence rate that these conditions cannot be ignored. Moreover, among the complications to be discussed, there are some which are known to cause sudden incapacitation. In fact, pregnancy may first present as serious, in certain cases lifethreatening events, namely, early spontaneous abortion, and, in particular, ectopic gestation.
Both conditions are associated with severe pain and profuse bleeding. The treatment of choice are curettage, laparoscopy or laparotomy, respectively, in certain cases operation is required within a few hours of onset of symptoms.
With respect to incidence medical statistics from Norway indicate that between 10 and 15 per cent of all clinically verified pregnancies are terminated in spontaneous abortion during the first trimester, corresponding on the average to approximately one spontaneous abortion in every individual of the female population. The rate of ectopic gestation has risen conspicuously during the last 15 years. Thus, the total national average shows a 3-fold increase from 1970 to 1985. The incidence rate has shown a particularly rapid rise among women 18 to 25 years old in which age group a 7-fold increase of ectopies have been observed to take place during this same period of 15 years. (Skjeldestad et al 1987). Several factors have been examined in order to explain the rapid rate of increase of ectopic gestation. Most authors agree that infections of the genital tract is the most important etiological factor, and that the number of infections is closely paralleled by the use of intrauterine devices (IUDs) for contraceptive purposes. Women who have undergone tubar surgery constitute another, however limited, risk group that nevertheless contributes significantly to the number of ectopic pregnancies. Extrauterine gestation has increased 6-fold in the group of operated women over a eight year period from 0.5 in 1000 conceptions (1976) to 3 in 1000 (1983) (Dahlstrøm et al 1989).
At the present there is no sign of a decline in the incidence of ectopic gestation. Moreover, the official vital statistics from the United Kingdom, the United States, Finland and Sweden over the same period of time confirm the Norwegian experience (ibid).

Apart from the rather dramatic events discussed, mere nuisances such as nausea and vomiting may effectively reduce the performance of personnel engaged in carrying out tasks which require their alert attention and precise execution. Different sources estimate that between 50 and 75 per cent of pregnant women suffer from nausea and regurgitation which, in typical cases, starts 2-3 weeks after having conceived to last for the next 10-12 weeks. The symptoms and sign of emesis gravidarum are easily provoked by exposure to an environment which is known to induce motion sickness.
It should be noted, that emesis may develop to hyperemesis characterized by persistant and severe nausea with violent vomiting to the extent of causing dehydration and serious metabolic disturbances - in extreme cases the foetus may perish.
Foetal development may also suffer from hypoxia and from exposure to radiation.
If there is the slightest evidence of harmful effects to the foetus carried by pregnant aviators, expecting mothers should be removed from flying status. These are considerations which are given much attention in contemporary society, in Norway for instance, great trouble is taken to identify noxious influences, job-related ones in particular, and to remove pregnant females from potentially harmful environments.
It would be irresponsible to neglect similar hazards in military aviation.
Therefore, it is our opinion that the early complications to gestation are so serious and the incidence rate so high that the aeromedical advice must be to ground pregnant air crew.

Finally, the medical consequences of the operational requirements have to be considered in addition to the complications outlined, since adequate treatment of events depend upon skilled intervention in fairly well equipped institutions.
In Norway missions employing female air crew are frequently flown over the sea hours away from the nearest airport with hospital facilities. The weather is frequently bad especially during the winter season, thus, separating crew members even further from institutions capable of providing necessary treatment. Even cases which do not require immediate medical attention may become an increased burden on a busy crew and cause disruption of procedures essential to mission accomplishment. Likewise, a crew member whose performance is significantly impaired due to even a minor condition is no asset to a military flight on a demanding mission. Pregnancy clearly interferes with combat readiness.

To sum up: Complications to pregnancy during the first trimester are several and the incidence rate is high. Some events are serious to the extent of jeopardizing flying safety, others will definitely interfere with successful completion of missions. Moreover, it is not unlikely that pregnant military aviators may be exposed to noxious stimuli harmful to the foetus.
For these reasons female aviators should be removed from flying status upon conception and grounded for the first trimester at least. Since such a period on the ground in most cases would require retraining after three months of absence from flying, it seems logical not to attempt to have pregnant females retrain for a few weeks, only to ground them for a second time as they enter the third trimester of gestation.
It is presently the policy of the Royal Norwegian Air Force to take female air crew off flying status when pregnancy has been diagnosed.

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EKG FINDINGS IN FEMALE AVIATORS IN THE US AIR FORCE

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SUMMARY

The initial EKGs from 309 female aviators and 309 age-matched male aviators were read to compare the prevalence of findings. Abnormal readings were unusual, as would be expected in this selected group. 1.3% of the males and none of the females had abnormal readings, a difference which is not significant (p = .0455). The abnormal readings were two cases of left anterior hemiblock and two of Wolff-Parkinson-White. Possibly abnormal findings, which required a second order workup to rule out the presence of cardiac disease, occurred at a similar rate between the groups (22.7% of females vs 16.2% of males, p = .0634). The preponderance of possibly abnormal findings in women were due to nonspecific ST and T-wave abnormalities. Normal variant tracings were more common in men (60.2% female vs 74.1% male, p = .0004) while women were more likely to have an EKG without significant finding (17.1% females vs 8.4% male, p = .0018). These findings, in our opinion, support the concept that EKG criteria that were developed for men can be used aeromedically for women.

INTRODUCTION

The first published paper on recording the electromagnetic force from a beating heart was published in 1887 by Waller[4]. Einthoven, the father of diagnostic electrocardiography, published a paper in 1903 which described the basic methodology and nomenclature that is still in use today[5]. In a 1912 Lancet article Einthoven described how the technique of electrocardiography could be used diagnostically. Important aeromedical contributions of the past include the cardiovascular studies begun in World War II by the Royal Canadian Air Force on all entrants into aviation training[2]. Similarly, in 1944 Graybiel published his article describing the EKG findings in 1000 asymptomatic males entering the US Navy Aviation Training. In 1957, the US Air Force became the first U.S. Military Service to require EKGs on flying personnel. The central repository for these EKGs resides at the USAF School of Aerospace Medicine From this institution, Dr. Lawrence Lamb's group published a number of articles in the early 1960's which described the electrocardiographic findings in asymptomatic men. After nearly 30 years these studies are still used as the references for the prevalences of normal and abnormal EKG findings. One major shortcoming of these studies is that the EKGs were only obtained from men. The purpose of this study is to determine the prevalence of EKG findings in healthy female aviators as compared to age-matched male aviators.

METHODS

For this study, we identified EKGs of women who had completed pilot or navigator training. Only the initial EKGs were read. Since women began to fill aircrew positions in 1975, that year was the starting point for the search of our files. Since approximately one year is required to complete pilot training, the endpoint for this group was 1988, rather than 1989. Using a computer search of our files, an equal number of EKGs on age-matched males were identified for review as well. The EKGs thus identified were retrieved, copied, and masked for identifying data. Each EKG was read twice by experienced physicians, who were blinded as to the identification, sex, and medical data of the subjects. Discrepancies between the readers were arbitrated by a third reader who was blinded to the identity of the subjects and to the identity of the previous readers, but not to their readings. All data acquired were entered twice, independently, into a computer file to assure accuracy. Diagnostic criteria were those used by Lamb's group in the 1962 publication[1] or standard textbook definitions[7,8]. Conditions for which criteria were nonconcurrent between reference sources, or conditions for which a high probability of reader disagreement existed, were addressed by assigning new definitions in advance.

Based upon the most significant findings for a given tracing, the EKGs were divided into four major categories - normal, normal variant, possibly abnormal or abnormal. Since an EKG often revealed many findings of varying significance, the overall category was based on the finding with the greatest aeromedical implication. For example, if an EKG revealed abnormal findings of left anterior hemiblock, in conjunction with the normal variant finding of sinus bradycardia, the EKG was categorized as "abnormal". If there were no findings of clinical or aeromedical import, the EKG was categorized as "normal".

The EKG data for each male and female pair were compared using McNemar's test for paired proportions to produce a chi-square statistic with one degree of freedom[6]. P values were computed for categories as well as the 15 most common EKG findings. Differences in the overall EKG categories were considered significant if the p-value was less than .01. Differences in individual findings were considered significant if the p-value was less than .0025.

RESULTS

A total of 18,459 aviators were identified with initial EKGs previously reviewed at the USAF School of Aerospace Medicine from 1975 through 1988. Of the 18,459 total, 473 were women. Of these 473 women, 309 had EKGs which were retrievable, of adequate quality, and had a suitable male match. The average woman was 21.99 years old at the time of the initial EKG. Mean weight was 60.4 kg and mean height was 167.7 cm. The average male counterpart was 21.97 years old, weighed 74.1 kg and was 178.6 cm tall.

EKG Category	309 Women	309 Men	
Normal	17.1%	8.4%	$p < .01$
Normal Variant	60.2%	74.1%	$p < .01$
Possibly Abnormal	22.7%	16.2%	NS
Abnormal	0.0%	1.3%	NS

Table 1 - Distribution of Four Major EKG Categories by Gender.

The prevalence of normal EKGs was higher in the female group. Normal variant EKG findings are rarely associated with a pathologic process, and men were somewhat over-represented in this category. Another category consisted of tracings with possibly abnormal findings which were suggestive of a pathologic process which could lead to impairment of the aviator. A small group of men had tracings which were frankly abnormal, and would have been disqualifying for flight training had they been read correctly at the time of the entry physical.

The normal variant EKGs were subdivided into three subgroups: terminal conduction variations, hypervagotonic findings, and early repolarization. The first subgroup, that of terminal conduction variations, includes the $S_1S_2S_3$ pattern, an RsR' in V_1 or V_2, terminal conduction delay, and indeterminate axis.

Terminal Variations	26.2% Women	39.8% Men	$p < .01$
$S_1S_2S_3$	21.7%	36.3%	$p < .002$
RsR'	6.8%	8.8%	NS
Terminal conduction delay	6.1%	12/6%	NS
Indeterminate axis	2.3%	4.2%	

Table 2 - Distribution of Terminal Conduction Variations by Gender

One-third of the total EKGs in this study revealed one or more terminal conduction findings, women were less likely to have these findings than men (See Table 2). The finding of a terminal delay was defined as a terminal S-wave in leads V_5 and V_6 equal to or exceeding .04 seconds in duration. The $S_1S_2S_3$ pattern was the only finding in this subgroup which was significantly more common between the sexes.

Another subgroup of normal variant findings were those considered to be primarily due to the strong vagal tone found in young, healthy subjects. Since these findings are particularly common in athletes, we also refer to these as athletic hearts. When such individuals exercise, vagal tone is withdrawn and the finding disappears.

Hypervagotonia	72.5% Women	74.4% Men	NS
Sinus bradycardia	48.5%	54.0%	NS
Sinus Arrhythmia	58.9%	54.0%	NS
Atrial Rhythm	1.6%	1.9%	NS
First Degree AV Block	1.0%	1.9%	NS
Junctional Rhythm	0.0%	0.3%	
Escape Beat	0.3%	0.6%	
Wandering Atrial Pacer	1.9%	1.3%	

Table 3 - Distribution of Hypervagotonia Normal Variants by Gender

The normal variant findings were equally distributed amongst the EKGs irrespective of gender. Sinus bradycardia is very common and occasionally the heart rate is remarkably slow. In Graybiel's group of 1000 aviators, the slowest heart rate was 38 bpm, while in Lamb's survey of 67,375 the slowest rate was 39 bpm[2,3]. In our study the slowest rate was 36.5 bpm. Similarly, sinus arrhythmia was very common when defined as a beat-to-beat variation exceeding .16 seconds. Hypervagotonia findings were equally represented in men and women. There were no significant differences in any of the findings between the males and females.

Another common normal variation was that of early repolarization, defined as an ST elevation of more than 1 mm in two or more leads (excluding V_2-V_4). Our results indicate that early repolarization is very common amongst the males but occurs only one-third as frequently in women (Table 4).

Normal Variants	81.6% Women	90.3% Men	p< .01
Terminal Conduction Variations	26.2%	39.8%	p<.01
Hypervagotonia	72.5%	74.4%	NS
Early Repolarization	11.0%	39.5%	p< .01

Table 4 - Distribution of Normal Variants by Gender

In summary, the normal variant findings are somewhat less common in women than in their male counterparts. Hypervagotonia findings are rather equally distributed between the two groups, while men more commonly have early repolarization and terminal conduction variations.

Possibly Abnormal EKGs	22.7% Women	16.8% Men	NS
Sinus Tachycardia	0.3%	0.6%	
Premature Atrial Beat	0.3%	1.0%	
Premature Ventricular Beat	0.0%	1.0%	
Short PR Interval	0.0%	0.3%	
ST/T-wave Changes	15.5%	7.4%	p<.01
Prolonged QT Interval	0.0%	1.0%	
Infarct Pattern	0.0%	0.6%	
Low Amplitude QRS Pattern	3.9%	2.6%	
Right Axis Deviation	0.6%	2.3%	
Left Axis Deviation	0.0%	1.3%	
R/S in Lead V_1	0.6%	1.0%	NS
Poor R-wave Progression in V_{1-3}	3.9%	3.9%	NS

Table 5 - Distribution of Possibly Abnormal EKGS by Gender

Possibly abnormal EKGs are those with findings suggesting the possibility of a serious underlying process, even if the potential is relatively small. When found these abnormalities require a second order workup. If the second order workup rules out the presence of an organic basis for the abnormality, the applicant is allowed to start flight training. EKGs representing possibly abnormal findings were somewhat more common in women. The rhythm and axis abnormalities are over-represented among men, while women more commonly reveal nonspecific ST and T-wave abnormalities.

Frankly abnormal EKG findings were unusual in this study, as might be expected. Had they not been overlooked at the time of the initial entry physical, the candidates would not have been allowed into pilot or navigator training. If an abnormal EKG finding is discovered <u>after</u> training, these individuals are allowed to continue flying if a second order workup reveals no disqualifying defect. WPW pattern is a short PR interval (PR< .12 sec) and a wide QRS complex (QRS > .12 sec), with a characteristic delta wave. WPW pattern may be suggested by borderline, or even normal, intervals in the face of delta waves. Only two of the men had this finding, 0.6% of the total, but it is still over-represented. In Hiss and Lamb's study of 122,043 individuals, WPW pattern represented .15% of all EKGs. Left anterior hemiblock is defined as an axis more leftward than -45 degrees with small Q waves in I and avL. Again, two of the men and none of the women had this finding. There were no frankly abnormal EKG findings noted in women.

Abnormal EKGs	0.0% Women	1.2% Men	NS
Wolff-Parkinson-White Pattern	0.0%	0.6%	NS
Left Anterior Hemiblock	0.0%	0.6%	NS

Table 6 - Abnormal EKG Distribution by Gender

DISCUSSION

The purpose of this study was to compare the prevalence of significant EKG findings amongst female pilots when compared to an age-matched group of male pilots. Previous studies of similar populations had involved only men. As more women enter the aviation community, and come under scrutiny for the appearance of heart disease, it is important to remember that the guidelines used in evaluating aviators were developed for men. This study was prompted by the question of whether different criteria for cardiac evaluations were needed for women pilots.

Women were more likely to have an EKG without any significant finding, men more commonly had normal variant findings. There was no significant difference between these two groups for EKGs categorized as abnormal or possibly abnormal. However, women were more likely to have nonspecific or T-wave notching, abnormal T-wave axis, ST depression, ST straightening, lateral T-wave inversion, persistent juvenile T-waves, etc. The imbalance cannot be attributed to a single finding such as low voltage, since women predominate in all of these to a greater or lesser extent. In the US Air Force any of these, as a persistent change on a routine periodic EKG, results in a second order workup to rule out a structural or ischemic basis for the finding. We do not have enough experience at this point to know whether the

higher rate of nonspecific ST/T findings in women corresponds with a higher rate of cardiac abnormalities. Therefore, it would be premature to change the criteria for second order workup for women on the basis of these findings. Another consideration is that this study was limited to the initial EKGs. Subsequent EKGs were not read. Therefore, we do not have enough data to cogently provide an alternate set of guidelines at this point.

In summary, these data suggest that current criteria which were developed in the era of all-male aircrew do not, in our opinion, need to be amended for aeromedical purposes in women. A few cautions should be kept in mind. The main problem with this study was its small size, a problem that time will correct as more women become aviators. Selection bias due to the fact that these EKGs belong to individuals who have been judged physically fit to fly distorts the prevalence values given for these abnormalities. These frequencies do not apply to the population at large. Finally, these readings are unaccompanied by long term clinical correlation. As our female population ages, we shall see whether our male and female aircrew reveal different rates of disease for the same EKG findings.

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APPENDIX

FINDING	FEMALES	MALES	
sinus tachycardia	1	2	
sinus bradycardia	150	167	p = .2371
sinus node echo beat	1	0	
sinus arrhythmia	182	167	p = .1973
atrial premature beat	1	3	
atrial escape beat	1	0	
atrial rhythm	5	6	p = .7630
short PR interval	0	1	
junctional rhythm	0	1	
junctional premature beat	1	0	
junctional escape beat	0	2	
wandering atrial pacemaker	6	4	
first degree AV block	3	6	p = .3173
terminal conduction delay	19	39	p = .0065
left anterior hemiblock	0	2	
interventricular delay	0	1	
nonspecific ST/T-wave changes	49	23	p = .0011
low amplitude T-waves	12	8	
abnormal T axis/morphology	29	10	p = .0013
ST depression	5	2	
ST flattening/straightening	23	7	p = .0017
early repolarization	34	122	p = .0000
prolonged QT interval	3	0	
prominent T-wave	1	0	
right atrial enlargement	0	1	
anterior Q or QS pattern	0	1	
anteroseptal Q or QS pattern	0	1	
normal; no findings	53	26	p = .0018
WPW - Type A	0	1	
WPW - Type B	0	1	
low voltage QRS	3	0	
right ventricular hypertrophy	1	0	
left axis deviation	0	4	p = .0455
right axis deviation	2	7	p = .0956
indeterminate axis	7	13	
$S_1S_2S_3$	58	92	p = .0021
$S_1S_2S_3$ with RsR' in V_1 or V_2	9	20	p = .0411
R/S in V_1	2	3	
poor R-wave progression in V_{1-3}	12	12	p = 1.000
RsR' in V_1 or V_2	12	7	p = .2513
normal EKGs	53	26	p = .0018
normal variant EKGs	186	229	p = .0004
possibly abnormal EKGs	70	50	p = .0634
abnormal EKGs	0	4	p = .0455
EKGs with normal variant findings	252	279	p = .0024
hypervagotonia finding	224	230	p = .5870
terminal conduction variant	81	123	p = .0005
early repolarization finding	34	122	p = .0000

IMPACT ON WOMEN: A RETROSPECTIVE LOOK AT IMPACT ACCELERATION TESTING AT THE HARRY G. ARMSTRONG AEROSPACE MEDICAL RESEARCH LABORATORY

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ABSTRACT

In today's society, women are occupying an increasing number of previously male dominated jobs. This is especially true in the United States Armed Forces. Women have served as pilots in the military since the early 1970's (1973 for Army and Navy; 1976 for Air Force) but cannot be assigned to high performance, ejection seat aircraft unless they are an instructor or test pilot. Consequently, research has been directed at the 5th to 95th percentile male crewmember, and little information is available with respect to performance, limitations and potential dangers that might be encountered with female aircrew. In the Biomechanical Protection Branch of the Harry G. Armstrong Aerospace Medical Research Laboratory (AAMRL), women have routinely been used as subjects in impact experiments since 1976. Seven women of 132 total subjects (5.3%) have taken part in 110 of 2108 (5.2%) of the impact testing. Although the numbers are small, this paper will provide a retrospective review of the data obtained from these female subjects at AAMRL, compare them to the male subject data and determine if there are any trends.

INTRODUCTION

As early as 1910, only 7 years after the first aircraft flight by the Wright Brothers, women pilots began appearing at New York's Belmont Park Aerial Tournament. By 1912, they were soloing and performing acrobatics as well as any of their male counterparts (6). In World War II the military began using women as pilots to ferry military aircraft, tow air gunnery targets and be instructor pilots for the young Army Air Corps cadets. From that time period until 1973, women were not allowed a commission in the United States Military to serve as pilots (11). Now, however, women can and do receive all phases of the same demanding pilot training as their male counterparts, and recently have been allowed into ejection seat aircraft as instructor and test pilots. The near future may also afford women assignments in fighter aircraft, as their primary aircraft, whether combat conditions occur or not. Because of this, a need exists to determine if there are any limitations for female aircrew when compared to their male equivalents. Specific areas of investigation include acceleration tolerance, acceleration protection, responses to impact, strength capacity, and performance capabilities.

BACKGROUND

The Harry G. Armstrong Aerospace Medical Research Laboratory (AAMRL), located at Wright-Patterson Air Force Base, Ohio, routinely uses female subjects in all aspects of experimental testing. Women have participated in potentially hazardous testing at AAMRL since 1952 (12), when the first female subject was ejected in a laboratory test (Figure 1). Since that time many variables have been explored using women as test subjects. The experiments that have been conducted have included studies of human response to short-duration and sustained acceleration, evaluations of protective equipment, and investigations of human performance capability while under the influence of stresses including acceleration, noise and vibration. The AAMRL acquires volunteers from the general active duty military population. All of the female subjects at AAMRL have had prominent careers in responsible positions with backgrounds in audiology, biology, engineering, and contract management. Several have since obtained national as well as international recognition in their chosen fields.

Experimental impact research efforts that went beyond simple demonstration tests with female subjects were initiated in 1959. Headley et al (9) conducted experiments with ten men and one woman to study human response to high rate of onset impact. This research was vital to the development of the ground landing attenuators used on the encapsulated ejection seats for the B-58 and XB-70 aircraft. Six tests were performed without an impact attenuator to evaluate the tolerability of very short-duration, high-amplitude impact pulses with impact velocities up to 3 m/sec. Peak acceleration up to 38.5 G was measured with rates of onset exceeding 8000 G/sec. Forty tests were performed with impact attenuators at impact velocities ranging from 4.9 to 9.1 m/sec. The second series of tests produced trapezoidal acceleration-time profiles with acceleration magnitudes up to 15.0 G with onset rates of more than 6000 G/sec. This research program clearly showed that the rate of onset then prescribed by the Air Force, 200 G/sec, could be repeatedly exceeded without debilitating injury if proper restraint and body positioning were used. This experimental evidence led to the initiation of research to develop mathematical models of human impact response and, ultimately, to the use of these models to specify the interrelationships between impact parameters such as rate of onset, acceleration amplitude and impact velocity change.

No further experimental impact research with female subjects was performed at the AAMRL until 1976. The research programs in the 1960's and early 1970 s had addressed human impact tolerance issues associated with systems and equipment specifically tailored for men. These efforts included research for Projects Mercury, Gemini and Apollo of the National Aeronautics and Space Administration and tests of combat aircraft equipment.

In 1976 questions were raised about the validity of certain restraint system design criteria that would influence whether women and small men would be adequately protected by existing restraint configurations. Design criteria that were addressed by these experiments included shoulder strap and

lap belt attachment geometry, and restraint harness configuration. Impact tests were conducted with the acceleration vector in the -x direction. Nine males and two females participated in these experiments as volunteers. Tests were accomplished at levels of 6, 8 and 10 G with impact velocities of 6.5, 7.9 and 9.2 m/sec, respectively. Shoulder harness angles that were tested included 0 and 25 degrees, which was considered to be the maximum allowable range, and 35 degrees, the angle that would occur with an expanded range of lower allowable sitting heights for flying personnel. These experiments did not reveal statistically significant differences in any of the human response measurements for the 25 and 35 degree shoulder harness angles (4).

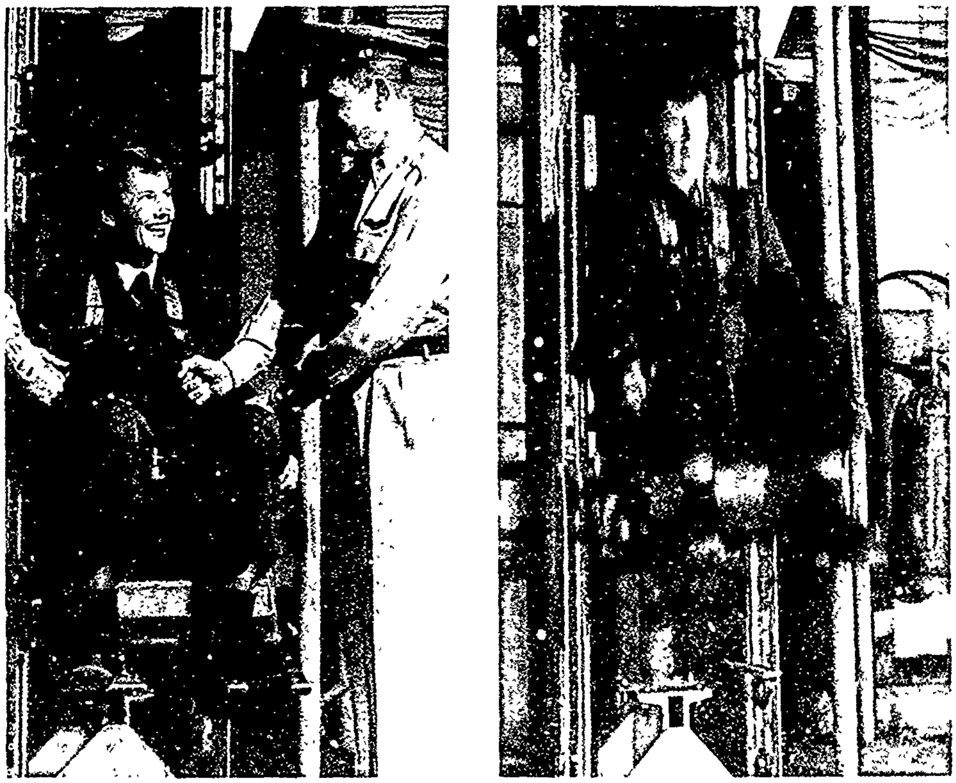

FIGURE 1. PHOTOGRAPHS OF FIRST EJECTION TEST WITH FEMALE SUBJECT

Accessible records of impact experiments dating back to 1976, reveal seven female test subjects out of a total test subject pool of 132, constituting 5.3% (1). Women have participated in 110 of the 2108 impact tests (5.2%) between 1976 and 1989 and have undergone impacts in all three principle directions (x,y,z) except for the positive x direction. Peak acceleration ranges are compared to the male subjects in the Table I. With the exception of the positive x direction, it is apparent that AAMRL s female test subjects have had equal opportunity, representative to their numbers in the test subject pool, to participate in the same testing parameters as their male counterparts.

Table I. Peak Acceleration: Female vs. Male Subjects

	Female		MALE	
G DIRECTION	MIN	MAX	MIN	MAX
+Gz	5.95 G	13.06 G	5.95 G	13.09 G
-Gz	3.9 G	10.05 G	3.70 G	10.09 G
+Gy	4.43 G	8.14 G	2.53 G	9.13 G
-Gy	3.00 G	4.53 G	2.86 G	15.00 G
+Gx	-	-	7.49 G	45.93 G
-Gx	5.90 G	11.01 G	5.50 G	30.56 G

ANTHROPOMETRY

Men and women differ considerably in their anthropometric make-up, specifically in terms of their stature, mass and inertial properties. They also differ in their gross anatomical make up in areas such as bone geometry and joint laxity. In reviewing the records of AAMRL s women test subjects, it can be seen that these seemingly subtle differences are actually important factors that can adversely effect the female aircrew member in an impact environment. The purpose of this paper is to explore some of these factors as a first step toward the eventual identification and quantification of female-specific impact guidelines to better assist researchers in the development of future cockpits and ejection seats that are safe for both men and women.

Selected anthropomorphic measurements of the female subjects at AAMRL were compared to male anthropometric data established in 1968 and the female Air Force anthropometric data of 1970 (Table II). These two data sets were used to determine the 5th percentile male and 5th and 65th percentile representative females shown in Table III. Also shown, are percentile figures for females that correlate with the 5th percentile male (2nd column).

Table II. Selected Anthropometric Measurements AAMRL Female Subjects

ID	Height (cm)	Weight (kgs)	Seated Height (cm)
S-5	157.5	52.06	83.3
G-2	159.5	52.97	84.8
K-3	173.0	68.25	88.4
Z-1	162.8	48.48	87.9
G-5	160.8	54.56	86.6
S-1	166.4	54.37	85.1
S-6	177.8	74.83	83.3

TABLE III. Summary of Selected Anthropometric Measurements for Representative Males and Females

	1967-68 5th percentile male (16)	Comparable percentile female (7)	5th percentile female	65th percentile female
Height (cm)	167.4	167.8-80th	152.9	165.0
Weight (kgs)	63.58	63.56-80th	46.39	60.00
Seated Height (cm)	88.1	88.3-80th	80.4	86.8

As illustrated, five of the seven subjects are below the 5th percentile male in height, weight and seated height. Subject S-6, however, was greater than the 99th percentile for the typical USAF female for height and in the 75th percentile for seated height. Also of interest, but not shown, is S 6's buttock to knee length which is greater than the 99th percentile for females and greater than the 95th percentile compared to USAF males (16). This particular aspect will be addressed later in the text

SPINAL INJURY POTENTIAL

To assess spinal injury potential, a mathematical model has been developed to estimate the probability of injury of the lower spine for a given acceleration-time history (2). It is a simple mechanical model which predicts the probability of vertebral body compression fractures in terms of a dynamic response index value that is computed from the acceleration being applied to a seat occupant. The probability of spinal injury with DRI level is a statistical function based on operational experience with USAF male aviators (5). Spinal injury potentials for female crewmembers ejecting from the T 37 and T 38 (undergraduate pilot training program aircraft) were calculated by Brinkley in 1977. These potentials were derived using dynamic response index calculations with the following assumptions (15).

1) Due to the lack of research data on females in the impact environment, specific acceleration exposure limits cannot be established. It is therefore necessary to utilize male data and make inferences with respect to females.

2) Although bone material in males and females exhibit the same strength characteristics, there are differences in the geometry and mass distribution which become significant factors in determining the impact responses to spinal accelerations and these have not been adequately studied

3) DRI values that have been calculated are presented to show the relative influence of ejected weight on the probability of spinal injury. They do not consider the possible difference in efficacy of the restraint harness due to differences in size between sexes nor do they consider the influence of the relatively higher attachment points for the shoulder straps of the restraint configuration on women.

Figures 2 and 3 illustrate that by decreasing the ejection weight the Dynamic Response Index increases and so, therefore, does the probability of spinal injury. Based on mass alone, it is clear that the fifth percentile female is at higher risk than the fifth percentile male, but the risk is still considered acceptably low.

KNEE INJURY

At AAMRL, no spinal trauma or injury has been sustained by any of the female subjects. In fact, the only significant injury incurred by our female subjects was a ligamentous knee injury which occurred in subject S-6 during a lateral, (acceleration imposed from left to right) impact. The subject was participating in a program to evaluate a modified F/FB-111 crew seat and its restraint system. At the time of injury the subject was undergoing an 8 G lateral impact. She had previously completed two similar tests at 4 G and 6 G without incident. In addition, fifty-nine other lateral impacts (19 at 8 G) had already been successfully accomplished on other members of the impact acceleration stress panel. The preprogrammed parameters for the mishap test were set for an acceleration of 8 G with an impact velocity change of 9.1 m/sec. The peak acceleration achieved was 7.96 G (average 7.36 G) with a velocity change of 9.1 m/sec. After the impact the subject complained of pain and while walking had buckling of her right knee. Clinically, the knee was unstable and post-impact X-rays under stress showed medial widening of the joint space. The subject subsequently underwent surgical repair at which time significant stretching of the medial collateral ligament (MCL) was noted with intraligamentous disruption of the anterior cruciate ligament (ACL). There was qualitatively little difference in the motion of the right knee, upon review of the high speed films, when compared to right knee motion in other similar tests. However, tracking the displacement of that knee frame by frame revealed a significant quantitative difference between the right knee and a comparable test as shown in Figure 4.

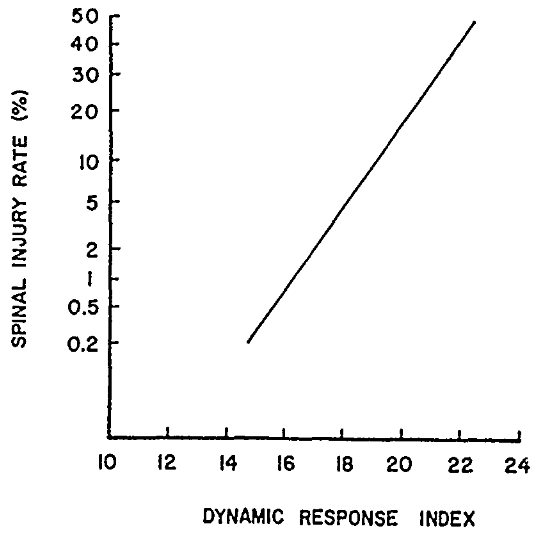

FIGURE 2. DISTRIBUTION OF SPINAL INJURY RATE

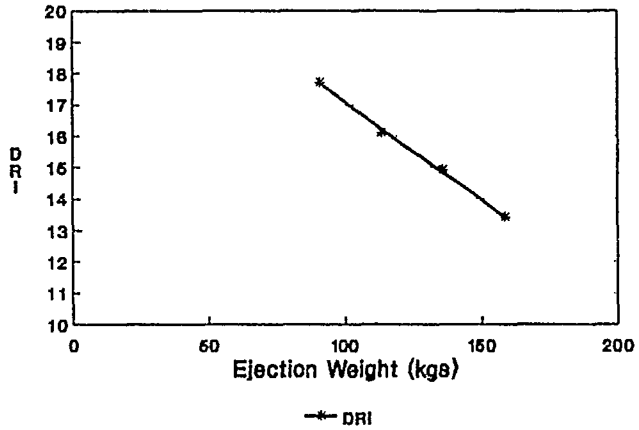

FIGURE 3. DRI VS EJECTION WEIGHT FOR M-5 CATAPULT

Several factors were examined as possible contributory factors in this case (3,10).

1) Extraordinary anthropometry. Subject S-6 was above the 99th percentile for the typical female in the United States Air Force in height and weight (above the 50th percentile for males). Additionally, her buttock to knee length was greater than the 99th percentile for females and greater than the 95th percentile compared to male USAF flying personnel. In conjunction with the seat configuration, this placed her knees in a 40 degree flexion a point at which the anterior cruciate ligament is lax and therefore, has minimal capacity for energy absorption. The long length also provides a greater lever arm for rotation about the stationary pelvis.

2) Bracing mode. The subject was positioned with her head braced against the headrest, arms extended and braced against the upper thighs, and her legs braced against a simulated rudder pedal footrest. Through review of the photometric data, it was determined that the subject s hand was no longer in contact with her right knee at the time of impact and therefore was not considered to be contributory to the injury. This subject did, however, demonstrate an exceptionally forceful lower extremity bracing which may have been a causative factor. Footrest load measured 4220 N immediately prior to impact and 4780 N during impact. Mean footrest loads taken from eight comparable tests revealed 2990 N and 3570 N, respectively.

3) Knee joint laxity: Post-injury exam revealed this subject to have joint laxity of her normal left knee, exhibited by a positive anterior drawer sign and patellar subluxation which may have predisposed her to knee injury during lateral impact. Hypermobility permits biomechanically disadvantageous knee joint positions, predisposing to ligament strain or tear. Women are known to have smaller muscle mass and increased joint laxity when compared to men (13). In this case, the mass was not considered to be a contributing factor; however, the increased joint laxity was.

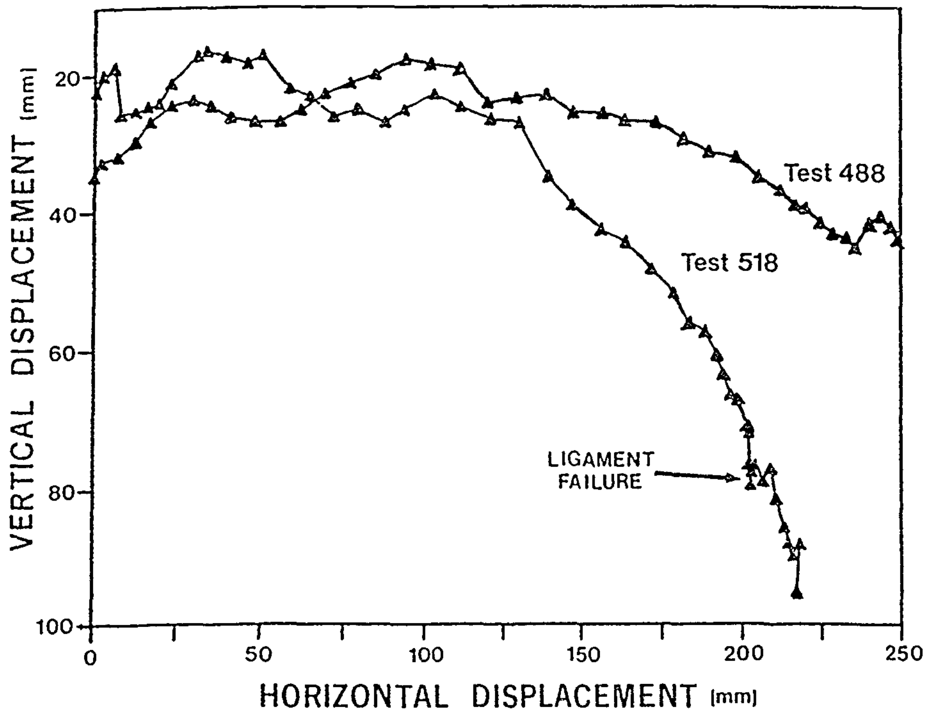

FIGURE 4. FRAME-BY-FRAME DISPLACEMENT OF RIGHT KNEE DURING IMPACT - COMPARISON OF TESTS 488 AND 518

Many conclusions were reached as a result of this mishap. First, the possibility of knee ligament injury should be considered when lower extremity flailing is permitted during lateral impact experimentation. Second, some subjects are at higher risk for knee injury than others, depending on several factors including sex. Therefore, special consideration is necessary for women when lower limb flailing is not prevented. Finally, this highlights the importance of biological variability among subjects on impact response and highlights the difficulty associated with defining absolute levels of human impact tolerance (3,10).

SUMMARY

In the realm of impact acceleration, there are many areas in which more exploration is needed. With women now occupying more and more previously male-dominated jobs, particularly in the field of aviation, all these areas need to be reexamined. As seen, there are many areas for which there are too few data to form sound conclusions, however, there are apparent trends in differences of size, shape and response to impact that need much more attention. AAMRL plans to continue to utilize women in all impact acceleration studies and to increase the number of female subjects on the impact acceleration stress panel so as to obtain enough data on female response to impact to make significant contributions to future cockpit and ejection seat designs.

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NOTICE

The human experimental efforts described in this report were accomplished in accordance with Air Force Regulation 169-3.

APTITUDE DU PERSONNEL NAVIGANT FEMININ NON PILOTE FRANCAIS, APRES KERATOTOMIE RADIAIRE

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RESUME

Les auteurs analysent l'expertise aéronautique ophtalmologique de 20 candidates hôtesses de l'air-CSS ayant subi une kératotomie radiaire pour myopie : dans plus de la moitié des cas une aptitude par dérogation a été accordée compte-tenu des bons résultats fonctionnels. A partir de cette expérience, les auteurs proposent un schéma général pour l'aptitude aux différentes spécialités du personnel navigant après kératotomie radiaire.

LISTE des ABREVIATIONS :

C.S.S. = certificat de sécurité sauvetage ; C.M.A.C. = conseil médical de l'aéronautique civile ; K.R. = kératotomie radiaire ; M = mois ; P.N. = personnel navigant.

INTRODUCTION

Si nous avons été confrontés dés 1981 au problème de l'aptitude aéronautique après chirurgie réfractive, c'est trois ans plus tard que celle-ci s'est banalisée et nous a amené à effectuer plusieurs études (1-2-3-4) en particulier sur le devenir fonctionnel de ces yeux opérés. Il nous a donc paru intéressant, en raison de leurs nombres, de reprendre les décisions d'aptitude aux emplois d'hôtesses de l'Air, depuis 1984, date à laquelle nous avons eu à statuer pour la première fois sur le devenir d'une candidate ayant subi une kératotomie radiaire.

PRINCIPE GENERAL ET RESULTATS DE LA K.R.

1 - <u>le principe général</u> de cette intervention (5-6) est de corriger chirurgicalement des myopies faibles ou moyennes de moins de 6 dioptries, en diminuant la puissance du dioptre cornéen antérieur qui représente les 2/3 du pouvoir réfractif global de l'oeil. Pour cela sont pratiquées 4 ou 8 incisions radiaires profondes (de 100 % de l'épaisseur cornéenne minimale) en dehors d'une zone optique centrale de 3 à 5 mm de diamètre. A ces incisions radiaires peuvent être adjointes des incisions relaxantes, concentriques au limbe, en cas d'astigmatisme.

2 - <u>résultats</u> :

Lorsque l'indication a été bien posée et le geste chirurgical bien réalisé, les résultats sont bons avec une récupération de 8 à 10/10 sans correction. C'est dire l'intérêt de la K.R. en expertise lorsqu'existent des normes visuelles minimales sans correction, surtout lorsque l'on sait que la myopie non corrigée est très pénalisante sur le plan optique (une myopie faible de 1,5 dioptries se traduira par une acuité visuelle inférieure à 2/10).

Néanmoins cet aspect très positif doit être tempéré par des considérations anatomiques et fonctionnelles avec des modifications dans le temps et surtout des variations inter-individuelles importantes :

Sur le plan anatomique la cicatrisation des incisions se fait par un bouchon épithélial qui va persister plusieurs mois, voire plusieurs années, maintenant le bon résultat fonctionnel mais fragilisant la cornée (certaines observations histologiques font état d'une absence de cicatrisation 4 ans après l'intervention) c'est ainsi que plusieurs cas de ruptures le long des incisions (7) ont été observés après contusion, dans les 6 mois suivant une K.R. ; il semble cependant, en règle générale que la cicatrisation soit suffisamment avancée au bout d'un an, pour que ce risque puisse être écarté sauf s'il existe un croisement d'incisions radiaires et relaxantes source de non-cicatrisation et de complications anatomiques locales graves. A plus long terme, outre l'imprévisibilité du délai de cicatrisation, il faut signaler la possibilité de néovascularisation périphérique dans le lit d'incisions qui auraient touchées le limbe ou après le port de lentilles pré-cornéennes en cas de résultat insuffisant. Par contre la perte cellulaire endothéliale post-opératoire, minime en l'absence de perforations, n'est pas évolutive à long terme. Sur le plan anatomique les résultats seront donc appréciés en fonction du recul par rapport à l'intervention, du nombre d'incisions, de la qualité de celles-ci, et bien sûr de l'absence de pathologie oculaire autre (sensibilité cornéenne - tonus oculaires - lésions rétiniennes dégénératives...)

Sur le plan fonctionnel plusieurs paramètres post-opératoires (8-9) méritent d'être étudiés ; c'est ce que nous ont enseignés depuis 5 ans l'examen et le suivi de 118 sujets opérés de K.R.

L'acuité visuelle post-opératoire sans correction : les résultats sont d'autant meilleurs et prévisibles que la myopie initiale est de faible degré (inférieure à 4 dioptries) ; lorsque les résultats précoces sont bons, ils le restent ; lorsqu'ils sont médiocres (4 à 5/10 sans correction) les progrès ultérieurs seront minimes. Les fluctuations nycthémérales de l'acuité visuelle, constantes dans les suites opératoires tendent à se stabiliser entre 6 mois et 1 an.

La réfraction oculaire peut se modifier pendant 3 ans, mais rarement au-delà de une dioptrie ; elle reste stable ensuite.

L'étude de la sensiblité à l'éblouissement (10), paramètre important dans les métiers de sécurité, montre en règle générale des altérations dans 60 % des cas jusqu'au 6ème mois post-opératoire puis une amélioration et une normalisation à un an ; il existe une corrélation avec l'aspect bio-microscopique, les incisions irrégulières ou obliques augmentant la sensibilité à l'éblouissement.

L'étude de l'intégration spatiale rétinienne aux contrastes colorés (11) montre une atténuation dans les basses fréquences spatiales tant que la cicatrisation n'est pas achevée.

Sur le plan fonctionnel les résultats seront donc appréciés sur l'acuité visuelle sans et avec correction, la réfraction après cycloplégie, la courbe de sensibilité à l'éblouissement et celle d'intégration spatiale rétinienne.

APTITUDE AERONAUTIQUE APRES K.R. CHEZ LES CANDIDATES HOTESSES DE L'AIR - CSS DEPUIS 1984

Compte-tenu des éléments que nous venons de voir, en particulier de la méconnaissance évolutive à très long terme, toutes les candidates ont été déclarées INAPTES dans les centres d'expertise du personnel navigant. Elles ont pu ensuite faire une demande de dérogation auprès du conseil médical de l'aéronautique civile ; les décisions de celui-ci ont été les suivantes :

Aptitude définitive : 11 cas, 7 à 11 mois après l'intervention répartis selon le tableau suivant :

Délai après K.R.	7 M	9 M	11 M	13 M	14 M	15 M	17 M
Nombre de cas	1	2	2	1	2	2	1

Inaptitude définitive : 4 cas

Inaptitude temporaire : 5 cas, le plus souvent pour des délais post-opératoires insuffisants :

délai après K.R.	3 mois	4 mois	6 mois	7 mois
décision du C.M.A.C. : Inaptitude temporaire de durée :	6 mois 1 an	non précisée	6 mois	6 mois

Ces décisions sont superposables à celles prises chez les stewards où pour 15 cas de K.R. il a été décidé :

- 9 fois une aptitude définitive entre 6 mois et 19 mois après l'intervention ;
- 3 fois une inaptitude définitive (1 dyschromatopsie, et 2 fois oeil myope adelphe non opéré) ;
- 2 fois une inaptitude temporaire en raison d'un recul insuffisant.

COMMENTAIRES

1 - Commentaires sur l'aptitude des P.N. commerciaux civils concernés par l'étude

L'aptitude définitive concerne plus de la moitié des sujets ; elle suppose .

- *un délai post-opératoire* suffisant en règle générale de 1 AN, bien que celui-ci ait pu être ponctuellement rétréci pour de petites myopies unilatérales n'ayant nécessité que 4 incisions.
- *de bons résultats fonctionnels* appréciés sur l'acuité visuelle, la réfraction, la résistance à l'éblouissement, la courbe d'intégration spatiale rétinienne.
- *de bons résultats anatomiques* avec des incisions régulières n'atteignant pas le limbe, sans micro-perforation, sans croisement des incisions.

L'inaptitude temporaire a été prononcée le plus souvent en raison d'un délai post-opératoire insuffisant ; nous avons été frappés dans ce groupe par le nombre de sujets (environ 50 %) qui n'ont pas subi de nouvelles visites.

Les inaptitudes définitives peuvent être liées à une cause autre que réfractive mais le plus souvent elles sont dues à des résultats insuffisants sur le plan fonctionnel souvent corrélés à des résultats anatomiques moyens avec incisions irrégulières ou obliques, atteignant le limbe, parfois associées à des micro-perforations.

2 - L'aptitude des autres membres du P.N.

Pour le personnel civil : à partir de l'expérience acquise avec les hôtesses de l'air-CSS ayant subi une K.R., et bien que chaque cas soit discuté au C.M.A.C., on peut retenir que lorsque les résultats anatomiques et fonctionnels sont bons, l'aptitude est envisageable par dérogation après :

1 an pour pilote privé ; 3 ans pour mécaniciens navigants ; 5 ans pour pilotes professionnels (3 ans minimum dans certains cas très particuliers) ; 5 ans pour pilote de ligne (seulement 2 sujets ont été admis dont une femme ayant une grande expérience aéronautique antérieure).

En ce qui concerne le personnel navigant militaire, où aucune dérogation à l'admission n'est admise, notre attitude est actuellement la suivante : inaptitude définitive pour les candidats pilotes ; aptitude envisageable avec trois ans de recul post-opératoire pour les contrôleurs de circulation et défense aérienne, avec cinq ans de recul pour les mécaniciens d'équipage.

3 - Conseils à donner à un candidat myope envisageant une carrière de navigant :

Il nous paraît capital, avant d'envisager une K.R., que le sujet passe une pré-visite complète de façon à éliminer formellement une cause d'inaptitude générale ou ophtalmologique autre que réfractive ; lorsque seule la myopie pose un problème, il faut s'assurer que l'intervention est indispensable (de petites myopies compatibles avec une activité aéronautique ont été ainsi opérées à tort ; par contre des myopies importantes supérieures à 6 dioptries impliquent des techniques de chirurgie réfractive beaucoup plus complexes et imposent quasi-toujours une décision d'inaptitude). L'intérêt majeur de cette pré-visite sera donc d'informer clairement le candidat des délais post-opératoires nécessaires et des risques concernant son aptitude future dont certains sont mal prévisibles (paramètres anatomiques et fonctionnels).

CONCLUSION

Si la K.R. permet d'envisager l'aptitude aéronautique des personnes qui auraient été inexorablement rejetées il y a une dizaine d'années, il faut néanmoins que tous, candidats et médecins, sachent parfaitement que l'inaptitude est un risque à courir avec les techniques actuellement utilisées ; peut-être la généralisation du laser "excimer", qui permet de réaliser des incisions parfaites et programmées en fonction du degré d'amétropie, nous amènera-t-elle à reconsidérer le problème dans quelques années.

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RELATIONSHIP OF MENSTRUAL HISTORY TO ALTITUDE CHAMBER DECOMPRESSION SICKNESS

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Summary

Records at the United States Air Force School of Aerospace Medicine, Division of Hyperbaric Medicine, were reviewed to determine the relationship between the incidence of altitude chamber decompression sickness (DCS) in females and menstrual history. The study period spans 11 years, from January 1978 to December 1988. Eighty-one records were suitable for study. A significant inverse linear relationship was noted between the number of days since the start of last menstrual period and the incidence of DCS. This relationship was noted with both Type I and Type II DCS. Lack of information on the population at risk precluded an analysis of the effects of birth control pills on this phenomenon. The underlying mechanism for the correlation between menstrual cycle and susceptibility to development of DCS is unknown. The conclusion is that women are at higher risk of developing altitude-related decompression sickness during menses, with the risk decreasing linearly as the time since last menstrual period increases.

Introduction

The United States Air Force (USAF) experience in the treatment of altitude-related decompression sickness is extensive. Records of all DCS cases treated in USAF hyperbaric chambers are maintained at the USAF School of Aerospace Medicine (USAFSAM), Hyperbaric Medicine Division, Brooks AFB, Texas. In-depth reviews of the USAF experience have been published by Davis et al. (1) and by Rayman and McNaughton (2). Bassett (3) has presented data demonstrating a four-fold higher incidence of altitude chamber DCS in women than men. This finding has been supported by a recent review over a 10-year period by Weien and Baumgartner (unpublished data), who found the incidence of DCS among females to be 4.3 times higher than that of men. This apparent increase in DCS among females has been largely unexplained. It is well known that the solubility of nitrogen in fat is five times that of lean tissues (4). Consequently, some investigators have speculated that the higher percentage of body fat in females has caused this increased incidence in DCS.

This paper investigates the role of menstrual history in development of altitude chamber decompression sickness using our records on the treatment of DCS cases. To our knowledge, no prior studies have addressed the relationship of menstrual history to the development of altitude-related DCS.

Methods and Materials

A review was conducted of patient records maintained at the USAFSAM, Hyperbaric Medicine Division. This division maintains files on all patients treated in USAF hyperbaric chambers, including the treatment of DCS. All files contain AF Form 1352 or SAM Form 306, Hyperbaric Patient Information and Orientation, which supplies information on patient name, age, sex, date of treatment, type of exposure, and form of treatment. These forms also list information on the use of birth control pills (BCP) and number of days since start of last menstrual period (LMP). For this study, patient data were reviewed for the 11-year period from January 1978 to December 1988. Due to lack of completeness and reliability, records on file before 1978 were not used. Patient records were reviewed for date of treatment, type of decompression sickness, (Type I vs. Type II), age, days since start of LMP, and use of birth control pills. It is assumed that all individuals exposed were in a good state of health, being required to possess a current USAF Flying Class III physical in order to enter the altitude chamber. It is also assumed that the time since LMP in females exposed to an altitude chamber environment is evenly distributed over a period of 0 - 29 days. After collection of data from the standardized form (AF 1352), the narrative summary and other documents in each patient record were reviewed to rule out errors in data recording.

Data on days since start of LMP were available on 85 of the 125 patient records available for review. Three of these records were excluded from study based on a prior history of hysterectomy. An additional patient was recorded, without explanation, as having her last menstrual period over 4 months prior to her treatment. Therefore, her record was also excluded. Eighty-one records remained for analysis. Collected data were entered on a microcomputer for compilation.

Results

Data from the study are shown in Table 1. The average age of females developing altitude chamber DCS was 26.5 years, with a range of 18 to 39 years. Of the 81 cases studied, 62 were Type I (joint pain only) DCS, and 19 were Type II DCS. All of the Type II DCS patients had neurologic symptoms, with or without joint pains. None of the patients experienced pulmonary DCS (chokes) or DCS shock, possibly because of rapid treatment in most cases.

The results of the study are shown in Fig. 1. In this graph, day 0 represents the first day of menses. The number of DCS cases declines linearly as the time since the start of LMP increases. The correlation coefficient for this graph is -.988, thus indicating a very close linear relationship. Grouping the data i. ifferent numbers of columns fails to affect this correlation coefficient.

If it is assumed that the time since the start of last menstrual period is distributed evenly among all females with altitude chamber flights, the distribution of the subgroup developing DCS is significantly different from the uniform distribution that would be expected (Chi-square (5df) = 16.41, p less than 0.01).

In this series, Type I DCS predominated, representing 76.5% of total cases. This percentage remained fairly uniform throughout the menstrual cycle. The percentage of cases of Type II DCS in each group in Figure 1 ranged from 18.2 to 27.8 percent.

Among women developing DCS, 27.2% were using BCPs (27.4% of Type I DCS cases and 26.3% of Type II DCS cases). The percentage of all women with altitude chamber exposure using BCPs is not known, nor is the type of pill nor the duration of use. As a result, no conclusions can be made regarding a correlation between BCP use and DCS susceptibility.

The solid line in Fig. 1 represents the incidence of both Type I and Type II DCS in males in relation to the groupings of females, obtained by using the incidence figures reported by Weien and Baumgartner. This demonstrates that the incidence of DCS in females approaches the incidence of DCS in males as the time since LMP increases. In the 25-29 day group, this difference becomes insignificant.

Discussion

Previous studies have established differences in the incidence and presentation of DCS among males and females. Davis et al. (1) noted, in a 1977 review, that females accounted for a greater number of difficult cases requiring more complicated management. No explanation was suggested to account for this difference. A 12-year study by Bassett (3) noted a four-fold greater attack rate of DCS among women than among men exposed to similar altitudes. Weien and Baumgartner (unpublished data) recently reviewed the USAF experience with DCS over a 10-year period, and noted an incidence of DCS among females of 206 87 cases per 100,000 exposures. (In males, the incidence is 48.08 cases per 100,000 exposures). They noted an attack rate of DCS which is 4.3 times higher in women than in men. Data on age, time since LMP, and use of birth control pills in females having altitude chamber flights without developing DCS were not available.

Many factors have been implicated as having an effect on individual susceptibility to DCS. Lam and Yau (5) noted that obesity and past number of episodes of DCS were important individual risk factors for development of DCS in compressed air tunnel workers. Dembert et al. (6) also noted an increased incidence of DCS in obese divers. In our series, obesity did not appear to play a role. No individuals exposed to reduced atmospheric pressure in USAF altitude chambers were obese, being required to meet physical standards for flying duties, including weight standards.

Dixon et al. (7) studied the incidence of venous bubbling and DCS in females exposed to a 7.8 psia suit environment. Thirty female subjects were studied. Five of the subjects (17%) developed symptoms of DCS, three of whom required recompression therapy. Dixon noted that 100% of females developing DCS were in the menses or early phase of their menstrual cycle, and only 32% of women who did not develop DCS were in the same phase of their cycle. This finding suggested a role of the menstrual cycle phase in the development of DCS.

Our current study provides further evidence for a significant role of menstrual cycle phase in the development of altitude chamber DCS in females. A clear correlation is noted between the incidence of DCS and the time since start of LMP, with a higher number of subjects developing DCS earlier in their menstrual cycle. This trend is present whether considering Type I DCS or the more serious Type II DCS. The role of the use of BCPs in DCS susceptibility could not be determined in this study.

Women play a significant and expanding role in activities which involve the risk of development of DCS, including diving activities, aircrew duties, and in present and future space operations, especially those involving extravehicular activities (EVA). Our findings have important implications for these activities, and cannot be taken lightly. It must be strongly emphasized that our findings are preliminary. Further studies, including those of a prospective nature, are required to confirm the role of menstrual cycle changes in susceptibility to DCS. This study does not address the mechanism responsible for our findings. The changes that occur throughout the menstrual cycle include many complex hormonal and metabolic changes, a description of which are beyond the scope of this paper. The implication of any of these specific changes in the susceptibility to development of DCS would be mere speculation It is clear that additional studies to determine the physiologic basis for this relationship are not only warranted but should be considered a high priority.

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Table 1. Distribution of DCS data

Days since start of LMP	Type I DCS BCP	Type I DCS No BCP	Type II DCS BCP	Type II DCS No BCP
0	1	3	0	1
1	1	3	0	1
2	2	0	1	0
3	0	4	1	0
4	0	2	0	2
5	2	1	1	2
6	0	4	0	0
7	3	1	0	1
8	0	1	0	0
9	0	1	0	0
10	3	2	1	0
11	1	2	0	0
12	0	2	0	0
13	0	0	0	2
14	0	3	0	1
15	2	4	0	1
16	0	1	0	0
17	0	0	1	0
18	0	1	0	0
19	0	1	0	0
20	0	3	0	0
21	1	2	0	0
22	0	0	0	0
23	0	0	0	1
24	0	2	0	0
25	0	0	0	1
26	0	0	0	0
27	0	1	0	0
28	1	1	0	0
29	0	0	0	0

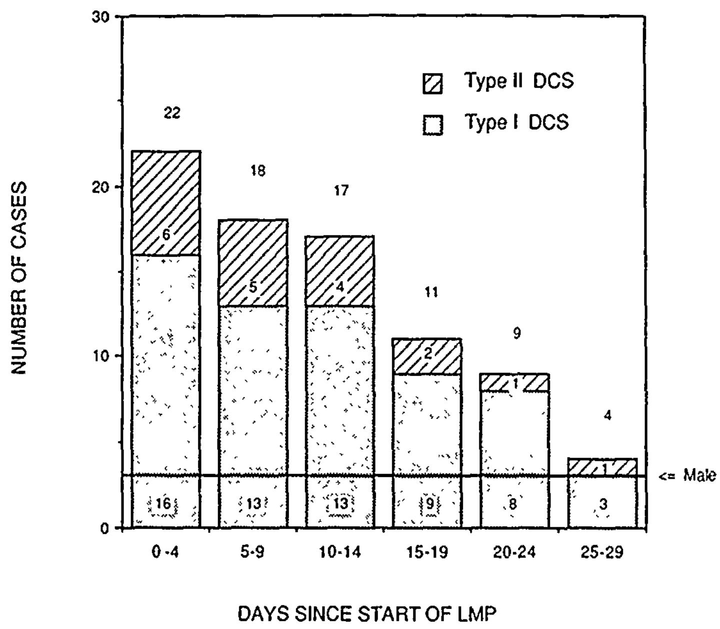

Fig. I. Time since LMP in DCS cases.

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- Pregnancy and flying
- ECGs in female aircrew candidates
- Physiological differences between male and female pilots
- Decompression sickness in female pilots

14. Abstract

There are now approximately one thousand female military aviators flying within the NATO nations. Twenty-eight papers were presented at an AGARD conference to review the experience of each nation with recruiting, selection, training and military operations of female aircrew. In addition, a section was devoted to the discussion of the physiological differences between male and female aviators, and pregnancy and flying. Once selected, there appear to be no basic differences in flight capabilities between men and women. There is a requirement to develop smaller helmets, oxygen masks and NBC respirators for females, and data were presented which showed that females are more susceptible to decompression sickness.

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